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A GENERALIZED INTACT STABILITY ANALYSIS PROCEDURE FOR MODULAR CONSTRUCTION PLATFORMS

ABSTRACT This report presents a generalized numerical procedure for evaluating the responses of a modular construction floating platform subjected to static loads. The theory employed is applicable to watertight pontoon platforms undergoing unlimited rotations. This procedure enables users to investigate platform stability under various deck load configurations. Users are able to design a pontoon platform with prefabricated modules, check the platform for static stability, and modify the platform in a sequence resembling the actual design process. This procedure has been automated in a FORTRAN program to relieve users of the tedious iterations for the exact submerged hull geometry. Theories employed, analysis scenario, and program organization are discussed. The functions of the subroutines are also described in detail. The results predicted by the numerical procedure are in general agreement with measurements obtained from a full scale at-sea test of a modular construction platform. The conventional closed form solution based on initial water plane geometry can seriously underestimate the rotational excursion of a platform, if the deck loads are a significant part of the total displacement, or their centers of gravity are high. The present theory, which accounts for the instantaneous water plane, will be used for evaluating the static stability of such structures.

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METRIC CONVERSION FACTORS

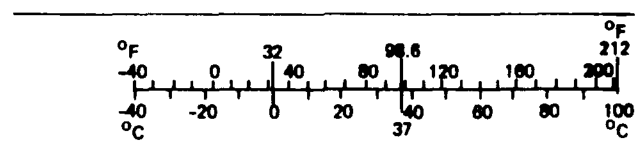
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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This report presents a generalized numerical procedure for evaluating the responses of a modular construction floating platform subjected to static loads. The theory employed is applicable to watertight pontoon platforms undergoing unlimited rotations. This procedure enables users to investigate platform stability under various deck load configurations. Users are able to design a pontoon platform with prefabricated modules, check the platform for static stability, and modify the platform in a sequence resembling the actual design process. This procedure has been automated in a FORTRAN program to relieve users of the tedious iterations for the exact submerged hull geometry. Theories employed, analysis scenario, and program organization are discussed. The functions of the subroutines are also described in detail. The results predicted by the numerical procedure are in general agreement with measurements obtained from a full scale at-sea test of a modular construction platform. The conventional closed form solution based on initial water plane geometry can seriously underestimate the rotational excursion of a platform, if the deck loads are a significant part of the total displacement, or their centers of gravity are high. The present theory, which accounts for the instantaneous water plane, will be used for evaluating the static stability of such structures.

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BACKGROUND

The procedure for assessing the stability of a floating structure with large water plane area subjected to small static loads is quite simple. Under this load condition, the water plane area remains practically unchanged throughout the loading process, such that the motion is linearly proportional to the loads. Consequently, the attitude of a floating body can be determined with a closed form solution. If the cargo loads represent a large portion of the displacement, such that the water plane continues to change during the loading process, the motions depend on the hull shape of the structure in addition to the load size and the initial attitude. The analysis involves a tedious iteration to determine the equilibrium submerged hull geometry. Pontoon platforms, which are typical examples, are likely to exceed the valid range for linear assumption. Their depths are usually very shallow compared with their horizontal dimensions, such that their decks are frequently flooded. They can appear rather stiff at small inclinations because of their large water plane areas. However, they quickly lose their stiffness as soon as the deck is flooded. The platform can continue to rotate without additional load and eventually capsize. The closed form solution, which is based entirely on the initial water plane geometry, can seriously overestimate the stability of a pontoon platform. A generalized analysis procedure, taking into account the variation of water plane as the floating body undergoes large motion, is required.

SCOPE

This effort developed a generalized stability assessment procedure, Intact Stability Analysis Program (ISAP), for a floating body of arbitrary shape under static cargo loads. The body is assumed to be unconstrained and is free to drift in the lateral directions. Hence, only the motions in vertical plane induced by vertical loads are considered, i.e., the changes in draft as well as trim and list angles. Theories applicable to a body undergoing unlimited motion in calm water were derived and coded in FORTRAN language. This procedure is designed to reduce the effort of designing a modular construction pontoon structure. Users may numerically simulate a platform with modules and then check it for static stability in a manner resembling the actual trial and error design process. A full scale at-sea test was conducted to verify this procedure.

This report documents the development of ISAP and provides a guidance to the program users. The first part of this report presents technical insight into the program, including the scenario of the analysis, highlights of notable theories, and a brief description of the program organization, as well as the function of each subroutine. The second part of the report provides a step-by-step users guide for practical applications. The users guide explains in detail the input data file preparation procedure by leading the user through the program interactively. Sample input and output files (used to interpret the results of the analysis) are also presented. Key terminology is defined at the end of the report. A conclusion at the end

of this report outlines the general features and the capability of the program. The complete ISAP program is listed in the Appendix for reference.

SCENARIO OF ANALYSIS

This analysis determines the optimal configuration of a floating platform on a trial and error basis. The floating platform consists of pontoon cans. Users can use predefined cans or specify new cans for platform fabrication. All pontoon cans are watertight and do not contain any fluid. The light platform will then be launched vertically with its main deck parallel to the water surface. It will automatically find its equilibrium attitude. Cargo loads can be added or removed in a consecutive manner to investigate the response of the platform. The cargo sizes are unlimited, and so are the barge motions. The barge can undergo 360 degrees rotation. Users can return to the light ship condition to begin with a brand new load procedure, or return to the platform fabrication routine to modify the platform design. This analytical procedure is arranged to fit the following special features of a modular pontoon structure:

1. Modular construction

2. Floats of arbitrary shape

3. Unlimited rotations

4. Incremental loading procedure

THEORETICAL CONSIDERATION

Static Stability

The attitude of a floating body is determined by the interaction of gravity and buoyancy forces. If no other forces are acting, it will settle until these two forces are equal, and rotate until two conditions are satisfied: (a) these two forces are aligned, and (b) a slight rotation from this position will cause the two forces to generate a moment, which tend to move the body back to its original position. For most floating bodies, there exists at least one such position. The stability of a structure depends primarily on the geometry of the hull as well as the weights and their distribution of the structure and cargoes. Consider a floating body as shown in Figure 1, for example, the gravity force acts through the center of gravity (CG), G, and the buoyancy force acts through the center of buoyancy (CB), B, which is also the centroid of the submerged volume. Since the body rests in equilibrium, these two forces must be equal in magnitude and opposite in direction and act along the same vertical line. If the body is forced to rotate by a small angle, θ, from its equilibrium position, such that the submerged volume varies with its center of buoyancy B shifting to a new position, B^1. As a result, the buoyancy force will separate from the gravity force. These two forces form an unbalanced moment. The influence of this moment on the floating body varies according to the shape and the mass

distribution of the body, or more concisely the relative positions of B and G. Suppose that G is located below B, as in the case of Figure 1, the unbalanced moment always restores the body to its original equilibrium position, and the body is, hence, unconditionally stable. If G is above B as the cases of Figure 2(a), the unbalanced moment can either restore the body back to its equilibrium position if the inclination is small, or push the body to incline further if the inclination exceeds a certain limit, Figure 2(b). The limit is when the line of action of the buoyancy force passes the CG which depends on the distance BG. Most practical floating facilities are of the latter category, with their G above B. Therefore, the stability is often a critical issue.

Coordinates

Two global and two local cartesian coordinate systems are used in this analysis. The local coordinates are used to define pontoon cans and compute patch pressure forces. They will be referred to in this report as the "can" coordinate (Figure 3) and the "patch" coordinate (Figure 4), respectively. Two global coordinates (Figure 5), which will be referred as the "external" and "internal" coordinates, are used to define the barge geometries, forces, and attitudes. The external coordinate is a communication reference and the internal coordinate is a computation reference. All input data will be entered with reference to the external global coordinate. Data will be automatically converted into values in the internal global coordinates after entry. The local systems are related to the global system by a transformation matrix, A, defined by the location of the local origin and the orientation of the local axes in the global system.

$$\{x\} = x_o + [A]\,\{X\}$$

where A is composed of the directional cosines of the three local axis in terms of the global system. Details of the local coordinates will be addressed where these coordinates are used.

The origin of the external global coordinate can be set at any location of convenience on the barge, with the x' y' plane parallel to the main deck and the z' axis normal to the deck pointing away from the barge, see Figure 5. For convenience, the x' axis is arranged in the direction of the longer horizontal dimension of the barge. Barge geometry and load configurations are specified in reference to this coordinate. This coordinate is fixed to the barge and moves with the the barge. As a result, the coordinates of a point on the barge remain constant at any time. This arrangement greatly simplifies the procedure of adding and removing cargo loads in a consecutive manner.

The internal global coordinate system floats with its x-y plane attached to the water surface, and z axis pointing upward, with its origin in coincidence with the instant center of flotation of the barge.

Forces

The external forces considered for the static analysis include the weights of the platform and cargoes, and the buoyancy acting on the submerged volumes of the floats. All floats are watertight. The cargoes are completely secured to the platform so that no relative

movement is permitted as the platform rotates. Buoyancy forces are computed for each individual float at the specific instant.

Gravity. The gravity force is the sum of the weights of the constituent parts, equipments, and cargoes. In this procedure, pontoons are assumed to be rigid, and the cargo is assumed to be fixed to the barge and will not move as the barge rotates. The weight of each float including the assembly parts, standard equipment, and machinery attached to that float is calculated and stored separately. The results will be recalled for assembling the total weight of the platform. All deck cargoes are assumed to be point loads. In the case that cargoes of significant volumes are flooded, submerged weights of these cargoes will be used. The gravity forces are constant, fixed in a position with respect to the barge. As the barge rotates, the effective lever arms of these forces change, and consequently, the total moment due to the same forces also changes. This factor is of special importance for forces applied at large heights from the water surface and can cause a floating structure to capsize. A crane barge is one example. This program continues updating the lever arm of each load to account for the barge rotation. The computation procedure of the gravity force will be addressed later in the discussion of the computer subroutines DRYCAN and FABRIC.

Buoyancy. Buoyancy is the only restoring force that holds the floating body in a stable position. The buoyancy for a floating body is the sum of all pressure forces acting on the entire wetted surfaces. The conventional integration procedure for a ship-shaped hull based on sectional ship curves is not convenient for a body of arbitrary geometry. A generalized procedure was designed to automate the buoyancy calculation. Since the pontoon floats are usually formed by plates, the wetted surface of the floats are essentially plane polygons with three or more vertexes, which can be further divided into a finite number of triangles. The pressure force and moments imposed on a submerged triangular plate of prescribed vertexes coordinates can be calculated with a standard procedure as follows. The total buoyancy is the vector sum of the pressure forces exerted on the constituent triangle patches.

The integration of the pressure force on a triangular patch is illustrated in Figure 4, where a local coordinate system, O, X, Y, Z is defined with respect to the patch, and p_1, p_2, and p_3 are the pressure at the three vertices of the patch. Since the static pressure varies linearly over the area of a patch, the pressure can be expressed in terms of the local coordinates by:

$$p(X,Y) = a_0 + a_1 X + a_2 Y$$

The total pressure force on the patch is obtained by integrating p(X,Y) over the entire patch as shown in Equation 1.

$$F = \int_0^{Y_3} dY \int_{\frac{X_3 Y}{Y_3}}^{X_2 - \frac{Y}{Y_3}(X_2 - X_3)} (a_0 + a_1 X + a_2 Y)\, dX = (p_1 + p_2 + p_3)\, \frac{X_2 Y_3}{6} \quad (1)$$

The direction of this force is perpendicular to the area of the triangular patch, and its point of application is determined by integrating the X- and Y-moments of the pressure force, as given in Equations 2 and 3.

$$\bar{X} = \frac{1}{F}\int_0^{Y_3} dY \int_{X_1\left(1-\frac{Y}{Y_3}\right)}^{X_2\left(1-\frac{Y}{Y_3}\right)} X(a_o + a_1 X + a_2 Y)\,dX$$

$$= \frac{1}{F}\frac{Y_3 X_2}{24}\left[p_1\left(1+\frac{X_3}{X_2}\right) + p_2\left(2+\frac{X_3}{X_2}\right) + p_3\left(1+\frac{2X_3}{X_2}\right)\right] \quad (2)$$

$$\bar{Y} = \frac{1}{F}\int_0^{Y_3} Y\,dY \int_{X_1\left(1-\frac{Y}{Y_3}\right)}^{X_2\left(1-\frac{Y}{Y_3}\right)} (a_o + a_1 X + a_2 Y)\,dX$$

$$= \frac{1}{F}\frac{X_2 Y_3^2}{24}(p_1 + p_2 + 2p_3) \quad (3)$$

The transformation of the direction and point of application of the force to the global coordinate system of Figure 5 is illustrated in Figure 6. In this figure, o, x, y, z is the global coordinate system and O, X, Y, Z is the local coordinate system. Let **A** be the 3-by-3 directional cosine matrix relating o, x, y, z and O, X, Y, Z and let the coordinates of the origin O of the local patch system be expressed by (x_o, y_o, z_o) in the internal global system. Now note that the moment of the pressure force, F, about the local patch X- and Y-axes be given by:

$$M_x = F\bar{Y} \quad (4)$$

and

$$M_y = -F\bar{X}\text{, respectively.} \quad (5)$$

With these definitions, the transformation of forces from the local patch coordinates to global coordinates is given by Equation 6, and the transformation of moments by Equation 7.

$$\begin{Bmatrix} F_x \\ F_y \\ F_z \end{Bmatrix} = \mathbf{A} \begin{Bmatrix} 0 \\ 0 \\ F \end{Bmatrix} \quad (6)$$

$$\begin{Bmatrix} M_x \\ M_y \\ M_z \end{Bmatrix} = A \begin{Bmatrix} F\bar{Y} \\ -F\bar{X} \\ 0 \end{Bmatrix} + \begin{Bmatrix} 0 & -z_o & y_o \\ z_o & 0 & -x_o \\ -y_o & x_o & 0 \end{Bmatrix} \begin{Bmatrix} F_x \\ F_y \\ F_z \end{Bmatrix} \tag{7}$$

The total unbalanced forces are simply the algebraic sum of the patch forces.

Excursions

Once the forces and moments resulting from gravity and buoyancy at an instant are calculated, and the total unbalanced force and moment are determined, the variation in the submerged volume can be determined. Although the changes occur simultaneously, the barge is assumed to sink vertically from its previous equilibrium position without rotation, to a draft having proper buoyancy, before rotating to offset the upsetting moments. The equilibrium position is determined by a trial and error process. The incremental displacements are estimated using instant water plane area based on the concept of small displacement.

$$[k]\,\{d\} = \{F\}$$

where {d} and {F} are the incremental displacement and unbalanced force vectors, and [k] is the instantaneous stiffness matrix of the barge. The instantaneous stiffness of the barge is:

$$\{d\} = \begin{Bmatrix} d_3 \\ d_4 \\ d_5 \end{Bmatrix} \qquad [k] = \begin{bmatrix} k_{33} & k_{34} & k_{35} \\ k_{43} & k_{44} & k_{45} \\ k_{53} & k_{54} & k_{55} \end{bmatrix} \qquad \{F\} = \begin{Bmatrix} f_3 \\ f_4 \\ f_5 \end{Bmatrix}$$

This matrix is symmetrical with the upper triangle elements specified as:

$$k_{33} = A_{wp}$$

$$k_{34} = k_{33} \times (y_g - y_f)$$

$$k_{35} = k_{33} \times (x_g - x_f)$$

$$k_{44} = I_{yy}$$

$$k_{45} = I_{xy}$$

$$k_{55} = I_{xx}$$

where A_{wp} is the water plane area, x_g, y_g, x_f, and y_f are location coordinates of CG and CF, and I_{xx}, I_{yy}, and I_{xy} are the second moment of inertia of the water plane.

The equilibrium condition at the new position will be examined in the same procedure. The iteration continues until the unbalanced forces and moments vanish. In case the incremental rotations at any time exceed certain preselected limits, which is five degrees in this version, the rotations will proceed in steps. The barge will rotate by the limit amount and pause for reevaluation of the instant stiffness matrix and unbalanced forces. The barge will gradually find its stable position. Analysis can be continued for the next load changes.

COMPUTER PROGRAM

Program Organization

The program is arranged to provide high flexibility to permit modular construction and incremental loading in the analysis. It allows users to design a barge on a trial and error basis. Users can numerically construct a barge and test its performance with a series of static loads in a step-by-step manner closely simulating a real operation. Users can also modify the barge by adding pontoons without rerunning the program. The program is further arranged to minimize the user's effort of constructing pontoons, which is the most time consuming procedure of the whole analysis from the user's point of view. Most often used Navy pontoons and ISO pontoons are stored in a "shelf," which is a random access data file provided with this program. Users can add new pontoons to this shelf if so desired. The program can be executed in batch or interactive mode. When executed interactively, the program takes the user through the barge construction process with a series of easy-to-follow prompts.

The general organization of these programs is illustrated in Figure 7. The main program, ISAP, establishes the scope and controls the flow of simulation according to the user selected options. Actual computations are executed by subroutines in the next level. These subroutines and their major functions are listed as follows. GRTING posts a greeting frame to display administration information once the program is activated. DRYCAN builds pontoon cans to be used for barge construction to be conducted in FABRIC. WETCAN searches for the equilibrium position of the barge at each load step. LOAD specifies the loading configuration. The program can be paused at any load step to examine the results at that instant. ARCHIV manages the intermediate information required to resume the analysis after each pause. Other lower level subroutines execute the details of the analysis. Details of the subroutine program are discussed in the section of program listing.

The sequence of analysis is illustrated on the flow charts in Figure 8. The main program ISAP chooses the analysis options before calling DRYCAN to build pontoon cans. Each unique can must be defined before use. The newly built can may be stored on a "shelf" if desired. A user can also pick a prefabricated can from the "shelf," in which case the can selected will be copied to the core memory. Upon completion of unique can construction, the program proceeds to fabricate the barge by activating FABRIC. The new barge will be launched into the water by calling WETCAN. This subroutine determines the equilibrium position of the bare barge. The program will then activate LOAD to receive cargo and call WETCAN to determine the new equilibrium position. Cargo can be loaded all at once, or in batches of any number at each loading step. Removing cargoes may also be done by loading negative weights. This procedure will proceed until the maximum number of loads, which is 100 in this version, is exceeded. The analysis can also pause after a loading step to examine

the result at that instant. The intermediate information required to resume the analysis will be disposed in an external data file by ARCHIV. If the user decides to continue from where he left off, he can resume the program with the option to retrieve the intermediate information stored in the data file by the same subroutine ARCHIV. The user can also go back to change the barge configuration after a loading step without pause. This option allows the user to continue improving his barge design. In this case, the loading test must start over.

Description of Main Program and Subroutines

ISAP. ISAP is the main program that controls the flow of computation according to the user selected options. It also sets up the defaults and maneuvers the logic tapes of the input and output files.

GRTING. This subroutine posts a greeting frame that shows the administration information as soon as the program is activated.

DRYCAN. This subroutine constructs the pontoon cans to be used for fabricating the barge. Each unique pontoon can must be specified before it is implemented. The cans are constructed in a similar fashion as that normally adopted to create a finite element analysis model. The coordinates are specified in a right hand cartesian coordinate system as shown in Figure 3. The origin and orientation of axes can be arranged at the user's choice. However, for convenience, the origin is set at the lower left corner of the bottom plate with x- and y-axes run along the edges of bottom plate if possible. This results in positive coordinates for most nodes. A collection of nodes, usually the corner points, are specified first in a local right hand cartesian coordinate to establish a geometrical reference for the can. The local coordinate and the node number assignment must satisfy the convention as follows. The origin of the coordinate must be located at node point 1, with x- and y-axis directed from the origin to node points 2 and 3, respectively. Exterior plates, beams, and other members of the can are then specified by these nodes and the particulars of materials. Interior plates, e.g., compartment dividers, shall not be specified as plates in this program. This is due to the fact that the program calculates the hydrostatic pressure on the underwater portion of all plates, including interior plates that are not in contact with the water. Therefore, if bulkheads or compartment dividers exist, they must be treated as thin, flat beams. Since the program is intended for cans made of flat plates, it automatically checks if the vertexes of the plates are on a plane by calling Subroutine COPLAN. The straight edges of a can must also be specified by their end points in terms of nodes. This information is required for determining the water plane, if a can is partially afloat. Additional information required by this routine is the nominal deck area of a can when it is afloat in the water; a rough estimate of the deck area will be sufficient. This routine automatically calculates the total weight and its center of gravity according to the geometry and material specified by the user.

FABRIC. This subroutine fabricates the barge to be analyzed with unique cans specified in Subroutine DRYCAN. A global cartesian coordinate must be established according to the shape of the barge. A collection of reference points are first specified in terms of the global coordinates to provide a direction reference for implementing the element pontoon cans. Three default reference points are located at (0,0,0), (1,0,0), and (0,1,0) as

illustrated in Figure 9. These three points are usually enough to define a box-shaped barge. A barge is fabricated by selecting specific types of pontoon cans and planting their local origins at locations specified by global coordinates with their local x- and y-axis directed at locations specified by two pairs of reference points provided by the users. Pontoon cans next to each other in a barge are assumed to be rigidly connected. The local nodes and the structural elements of a can are converted into their counterparts in the global coordinates in the order that the cans are implemented. This routine accumulates the total weight and deck area, and calculates the center of gravity of the barge based on the particulars of the unique cans. The shape and structural construction of a barge will be printed for review as soon as the barge construction has been completed.

WETCAN. This subroutine executes actual hydrostatic analysis to determine the equilibrium position of a barge in the water. The bare barge fabricated in the subroutine FABRIC is launched in the water without a deck load. The barge is assumed to sink vertically to a nominal mean draft according to the total weight and the nominal deck area specified by the user. WETCAN will recalculate the new water plane and buoyancy and then search for the proper mean draft by iteration. At each integration step, WETCAN locates the new center of floatation and shifts the origin of the global coordinate to the new float center. Coordinates of all nodes will be updated in the mean time. As soon as the barge has sunk to the proper mean draft, it begins to rotate according to the unbalanced moments resulting from uneven distribution of the barge weights and the buoyancy. Searching for the final equilibrium position is also conducted by iteration. A barge can have more than one equilibrium position in some cases. The iteration can converge to one of these equilibrium positions depending on the loading procedure. In order to avoid possible over-shooting and lead to a wrong solution, barge rotations will proceed in a incremental fashion. The routine sets a maximum increment to five degrees. WETCAN recalculates the draft, water plane, center of flotation, and the unbalanced moments, and then determines the new position until the equilibrium condition is satisfied. The global coordinate will be moved to the new center of flotation at each iteration step and the nodal point coordinates will be updated accordingly.

The barge is now ready to receive deck cargo. The cargoes can be placed in steps or all at once. All cargoes are assumed to be loaded slowly and do not exert dynamic effects on the barge. The deck cargoes will create extra unbalanced forces and moments to sink and rotate the barge further. At each loading step, WETCAN goes through the same procedure as that used to determine the equilibrium position of the bare barge when it is first launched into the water. The location coordinates of deck cargoes will be updated as the global reference shifts at each integration step. WETCAN determines the equilibrium position of a bare barge at the first call to the routine, and determines the equilibrium position of the barge under a new set of cargoes at consequent calls.

LOAD. This subroutine specifies the loading configuration on the deck. Cargoes can be loaded incrementally or all at once. The locations of cargoes will be specified in reference to the global coordinate setup for barge fabrication. The routine will automatically convert these coordinates to the coordinate referring to the actual global system at the instant of loading. LOAD will then calculate the unbalanced forces and moments with respect to the global coordinate and call Subroutine WETCAN to determine the new equilibrium position.

ARCHIV (I). The ISAP program is so arranged that the external loading can be placed on the barge either simultaneously or incrementally. If the latter is selected, the internal information needed to continue the execution for the additional loading will be stored in a temporary file. This temporary file will be accessed to retrieve the same information. The user must set the argument equal to "one" to save the internal information, or equal to "two" to retrieve it.

COPLAN (POST,N,ICODE). This subroutine checks if the area enclosed by N spatial points specified by the position vectors POST is a plane surface. N shall not be less than four. Testing is carried out in groups of four points. These four points combined form three vectors as shown in Figure 10. All torques formed by any two of these three vectors should be co-linear, if these four points are on the same plane. Therefore, the scalar product of these torques vanishes.

$$T = V_1 \times V_2$$

$$S = V_2 \times V_3$$

$T \cdot S = 0$, if the four points are co-plane.

The test continues by replacing one of the four points with other points one at a time until all points are checked. ICODE will be set to one, if any point lies out of the common plane, to flag the condition before returning to the calling function. Otherwise, ICODE will be zero.

WTPLANE (K). This subroutine searches the water plane for each pontoon can. Since a pontoon can is usually made of flat plates, its water plane is a polygon with its vertexes located where the straight edges of the can emerge from the water, see Figure 11. The program steps through all edges specified in the pontoon can definition, and searches for the emerging points, if any. The area and second moments of inertia of the polygon, with respect to the global axis at the moment of consideration, are calculated by calling subroutines AREA and MOMIT2.

MOMIT2 (XX,NP,XXI). This subroutine calculates the second moment of inertia of an arbitrary polygon at the free water surface about the global coordinates parallel to the water surface, i.e., X and Y. The vertexes of the polygon are rearranged in a counterclockwise order as one looks from above in this subroutine. The polygon is divided into triangles, so that the second moment of inertia of each triangle can be calculated in a generalized procedure. The total moment of inertia will be the algebraic sum of the component triangles.

BUOY (K). This subtine calculates the buoyancy exerted on a pontoon can and the resulting moments with respect to a global origin at the instant. The results are obtained by integrating the hydrostatic pressure on the wetted surfaces of the pontoon can. The routine steps through the external surface and determines the submerged shape of each surface. The pressure force and its point of application are calculated by calling the subroutine PRESUR. The resulting moments are the vector product of the pressure force and the position vector of

the application point. The total force and moments are the algebraic sum of the contribution from each surface.

PRESUR (U,NPT,PRES,BMS). This subroutine calculates the hydrostatic pressure force applied on a partially submerged plate. The routine determines the shape of wetted surface and subdivides the surface into triangle elements. The force and moments are calculated by calling subroutine PRESU2.

PRESU2 (XG,P,PA). This subroutine calculates the pressure force, P, on a triangle patch specified by the position vector, XG, and the resulting moments, PA. The force and moment are calculated by Equations 3 through 6, respectively.

AREA (V,N,AR,CG). This subroutine calculates the area and the centroid of a N-sided plane polygon. The calculation is conducted by dividing the polygon into a number of triangles, whose areas and centroids can be calculated easily. The total area and the overall centroid are the sum and weighted sum of the components.

$$AR = \sum A_i$$

$$CG = \sum \frac{V_g(i) \times A(i)}{AR}$$

VECTOR (U,V,W,IOPT). This subroutine manipulates two spatial vectors, U and V, in the following fashion:

$$W = U \text{ (operator) } V.$$

where the "operator" can be addition (+), subtraction (-), vector product (X), or scalar product (·) for IOPT equals 1, 2, 3 and 4, respectively. The result is returned by vector W. In the case of scalar product, the result will be stored in the first element of the vector.

VERIFICATION WITH TEST MEASUREMENTS

At-Sea Test

A full-scale at-sea test was conducted to verify the performance of ISAP. Large weights were placed on a floating platform to observe the consequent motion excursion. The platform was composed of three ISO- sized pontoons linked together side-by-side, see Figure 12. Each pontoon is nominally 20 feet long, 8 feet wide, and 4.5 feet deep, and weighs 13,000 pounds in the air. The platform was lightly moored to the dock side in a harbor basin to prevent possible drift due to currents or loading operations. Fenders were used to separate the platform from the dock side. However, these mooring lines were kept slack and the fenders were free floating during data collection periods. The weather was sunny with a slight breeze

and the sea surface varied from calm to very slight swell with wave height less than 1 foot during the test. Four draft boards were attached at the corners to monitor draft readings. Draft variations at the corners were less than one half of an inch. Weights were slowly placed at the desired deck locations almost exactly with a crane and were secured to deck sockets by chains and hooks. Four certified weights, each weighing 2,500, 5,000, 10,010, and 50,300 pounds respectively, were used in combination to create different loading conditions. The light platform, which will be referred as Load Configuration 1, was on an even keel. The largest weight (50,300 pounds) was first placed at location "A" near the midship on the center line to sink the platform to the extent that the platform could be rotated to a partially submerged deck condition with reasonable amount of weights. This weight remained on the platform. This condition is referred to as Load Configuration 2. The other three weights were then placed at 2 feet from the edge near the dock side (Location "B"), one at a time to create Load Configurations 3, 4, and 5. The 10,010-pound weight at "B" would heel the platform to the margin of capsizing according to the present theory. Hence, no further attempt was made due to safety considerations. The load configurations are summarized in Figure 13.

Comparison

The theoretical ISAP model was used to simulate the at-sea testing. An identical platform of the test model was constructed and ballasted to the lightweight draft in the numerical model. Loads were then placed in the same order as the test procedure from Load Configurations 1 to 5. The attitudes of the platform under each load configuration are illustrated in Figure 14. The drafts at draft boards DB1 and DB2 predicted by the theory (circles) were plotted along with the test measurements (squares) in Figure 15. The comparison is exceptionally good. The theory predicts the motion excursion accurately, including the deck flooding cases. The predictions by the closed form linear theory are also presented in Figure 15 as triangles, for comparison purposes. The linear theory performed quite well under small loads, but substantially underestimated the motion excursion as soon as the deck was partially flooded. Deck wetting is a critical condition because a platform quickly loses stability and will capsize when subjected to a small amount of additional load. This consequence can be demonstrated by placing an additional load of 1,000 pounds at "B." The numerical model predicts a sure capsizing with this extra load. The result was included in Figure 14 as Load Configuration 6. The capsized attitude can be identified by a nearly zero draft at DB1 and a negative draft at DB2, in Figure 15. This indicates that the entire bottom plate is exposed in the air. The linear theory, on the other hand, predicts that Load Configuration 6 would rotate the platform just slightly more than Load Configuration 5.

DEFINITIONS

Key terminology used in this report is defined below.

Stability: A floating body rests in equilibrium at still water surface in such a manner that if, when inclined slightly in any way, it returns to its original position, then the body is stable. The stability of a floating body under static forces is referred as the static stability of the body. Static stability is measured by the maximum static force that a body can sustain before losing its stability.

Excursion: The distance that a floating body moves from its lightweight equilibrium attitude. The motion excursions can be translations or rotations.

Attitude: The stable, static position that a floating body holds in calm water.

Displacement: The total weight of the water dispelled by the submerged hull of a floating structure. This is equal to the total weight of a floating body.

Draft: The vertical distance from the lowest point of a floating body to the still water surface.

Trim angle: The acute angle between the longitudinal principal axis of a floating body and still water surface.

List angle: The acute angle between the lateral principal axis and the still water surface.

Water plane: The cross section of a floating body cut by the still water surface.

CONCLUSIONS

A numerical procedure has been developed to predict the attitude of a floating body of arbitrary shape in still water under large static loads. This procedure is capable of describing the behavior of any floating body undergoing unlimited motions up to capsizing, attributing to the use of two generalized numerical schemes to account for the large motions as follows:

(a) The procedure determines restoring forces by direct integration of the hydrostatic pressure over the entire wetted surfaces.

(b) The procedure continuously updates the water plane geometry, submerged volume, and lever arms of all weights and traces the motion in small steps until the body settles to a new attitude.

The second feature enables the present method to accurately locate the unstable condition of a floating body with a high center of gravity. This condition is not evident with the conventional closed form solution based on small motion assumption.

The calculation procedures have been coded in FORTRAN to automate the task of calculating the submerged geometry of the hull. Users are able to investigate platform stability under a series of deck loads. The program is specially designed to deal with rigid platforms composed of modular pontoons. All communications are made through a series of user friendly prompts. Users are able to numerically simulate a pontoon platform with prefabricated modules, launch the platform for stability test, and modify the platform in a sequence resembling the actual design process.

The performance of this procedure has been verified with full-scale at-sea testing of a modular construction platform. The procedure predicts platform attitude in close agreement with test measurements.

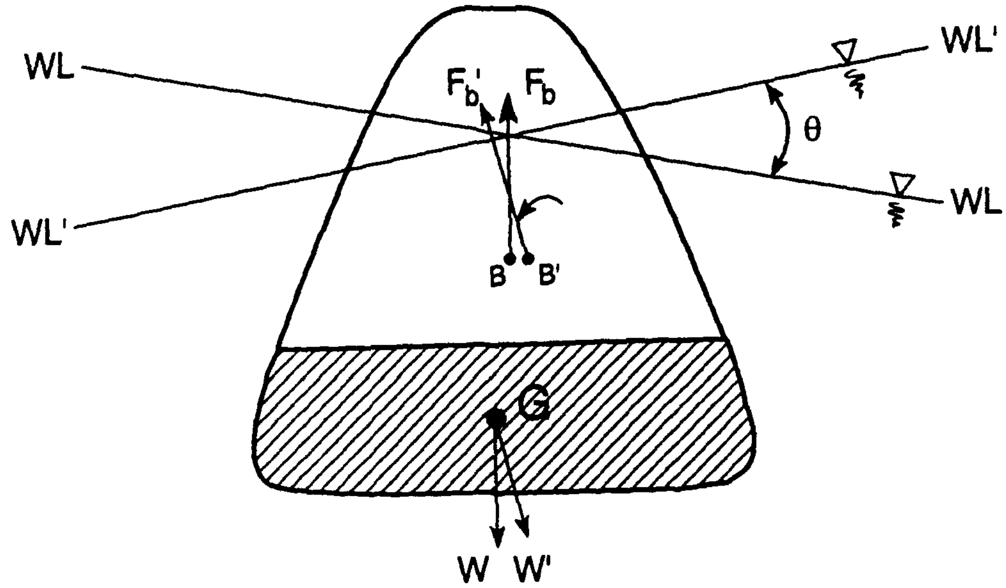
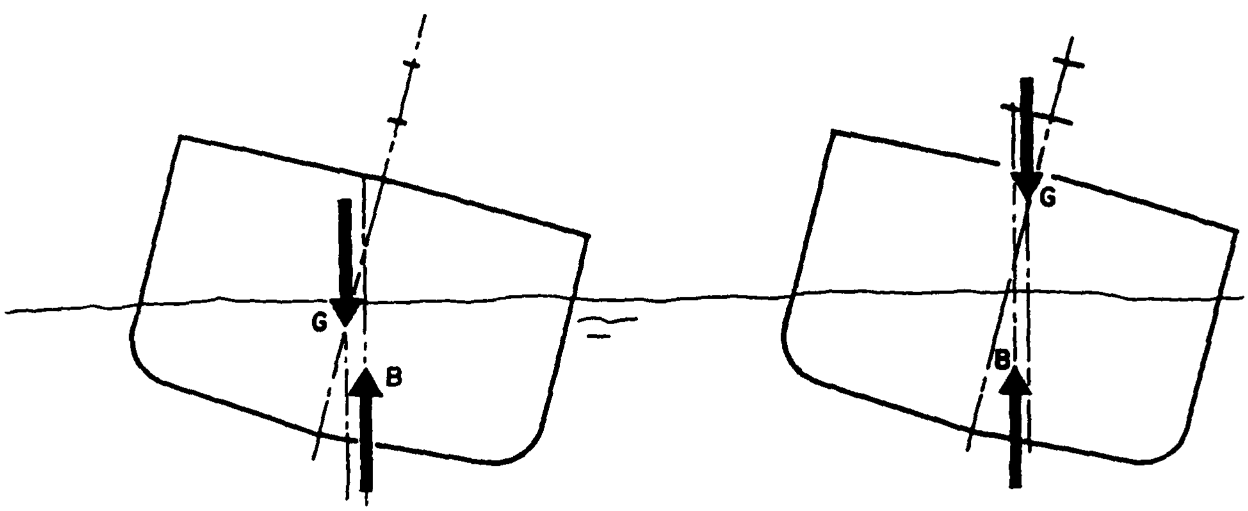
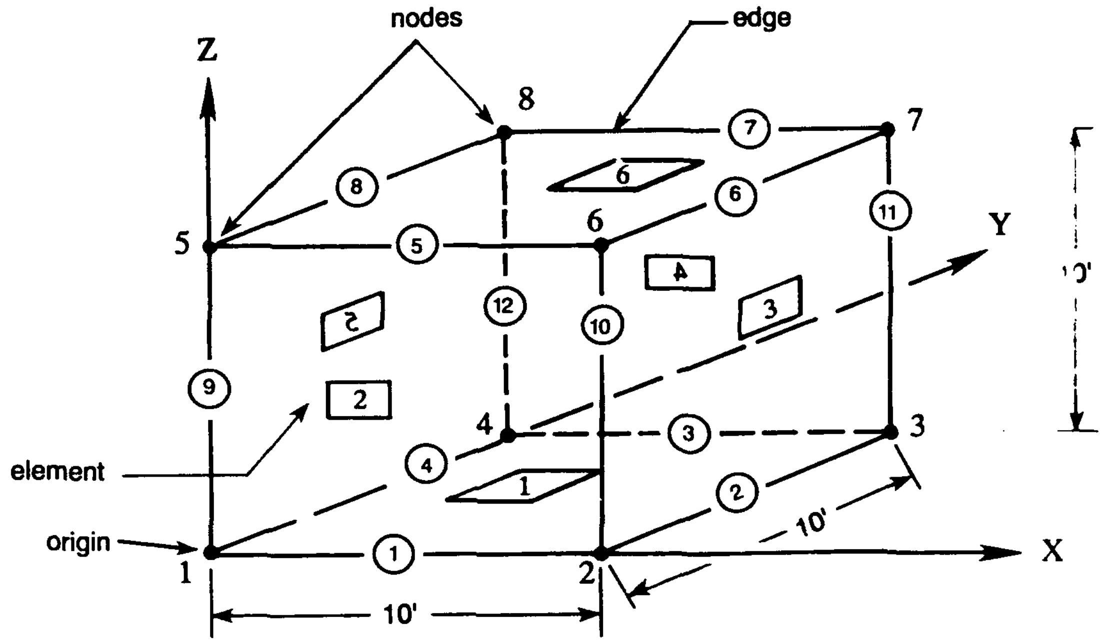


Figure 1.
Floating body with the center of gravity below the center of buoyancy.



(a) Positive stability **(b) Negative stability**

Figure 2.
Floating body with the center of gravity above the center of buoyancy.

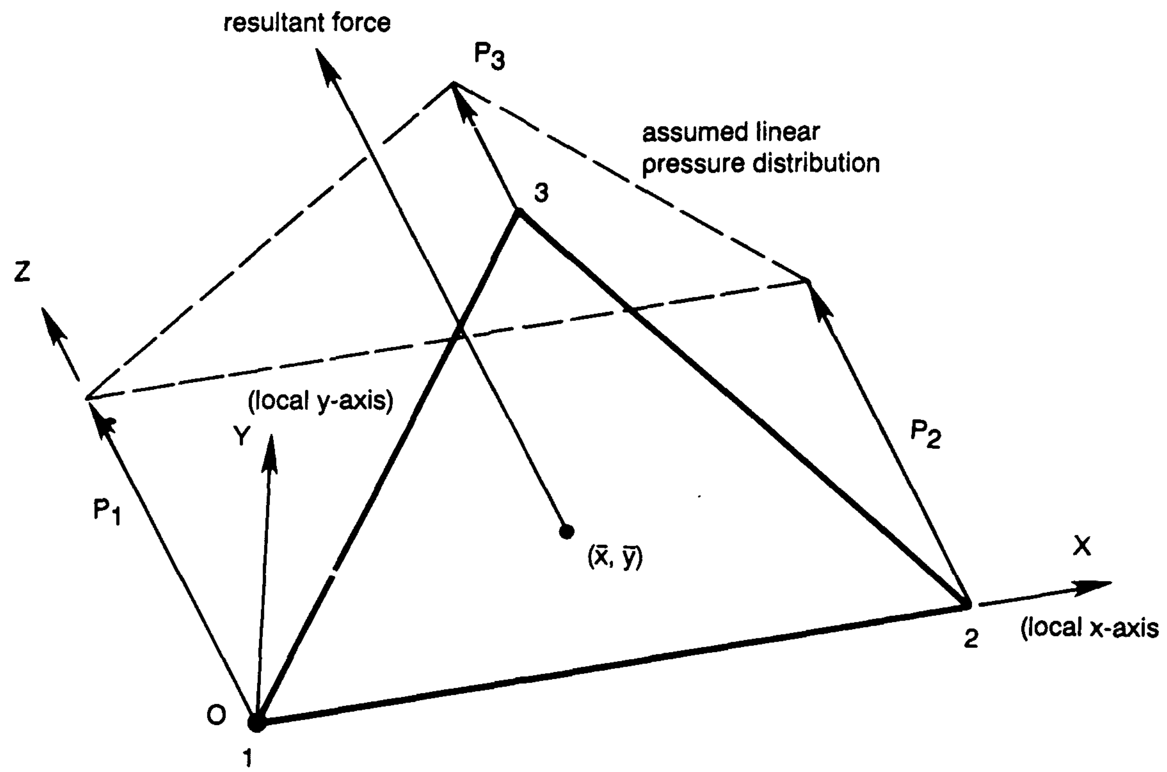


Nodes (numbers in parenthesis indicate coordinates):

1. (0,0,0)	5. (0,0,10)
2. (10,0,0)	6. (10,0,10)
3. (10,10,0)	7. (10,10,10)
4. (0,10,0)	8. (0,10,10)

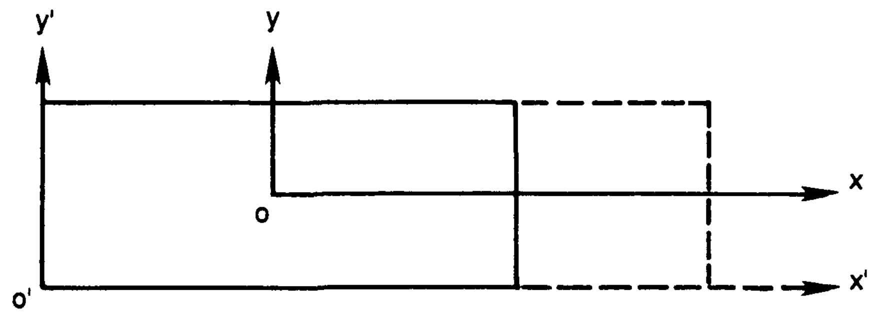
Edges ◯	Plates ▭ (numbers in parenthesis indicate Node I.D.)
1. (1,2)	1. (4,3,2,1)
2. (2,3)	2. (1,2,6,5)
3. (3,4)	3. (2,3,7,6)
4. (4,1)	4. (3,4,8,7)
:	5. (4,1,5,8)
:	6. (5,6,7,8)
:	
:	
:	

Figure 3.
Can coordinate system.

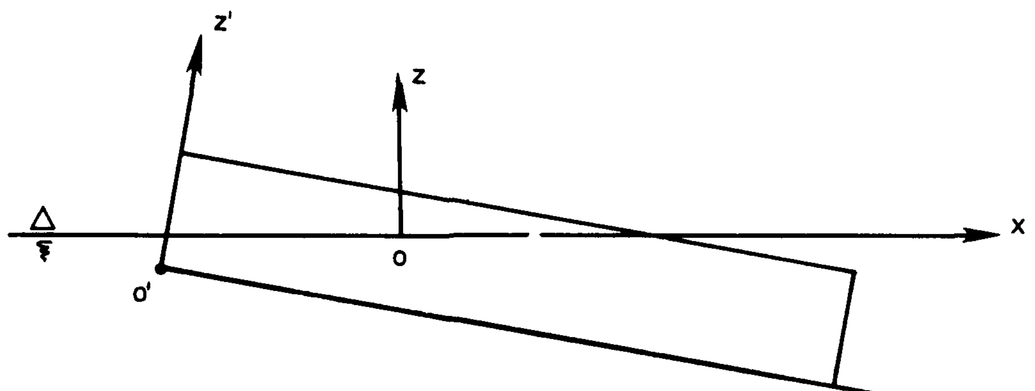


Local X-Y axes are in plane of patch.

Figure 4.
Patch coordinate system and the pressure distribution on the patch.



(a) top view



(b) side view

External global coordinates x'-y'-z'.

Internal global coordinates x-y-z.

Figure 5.
Global coordinate systems.

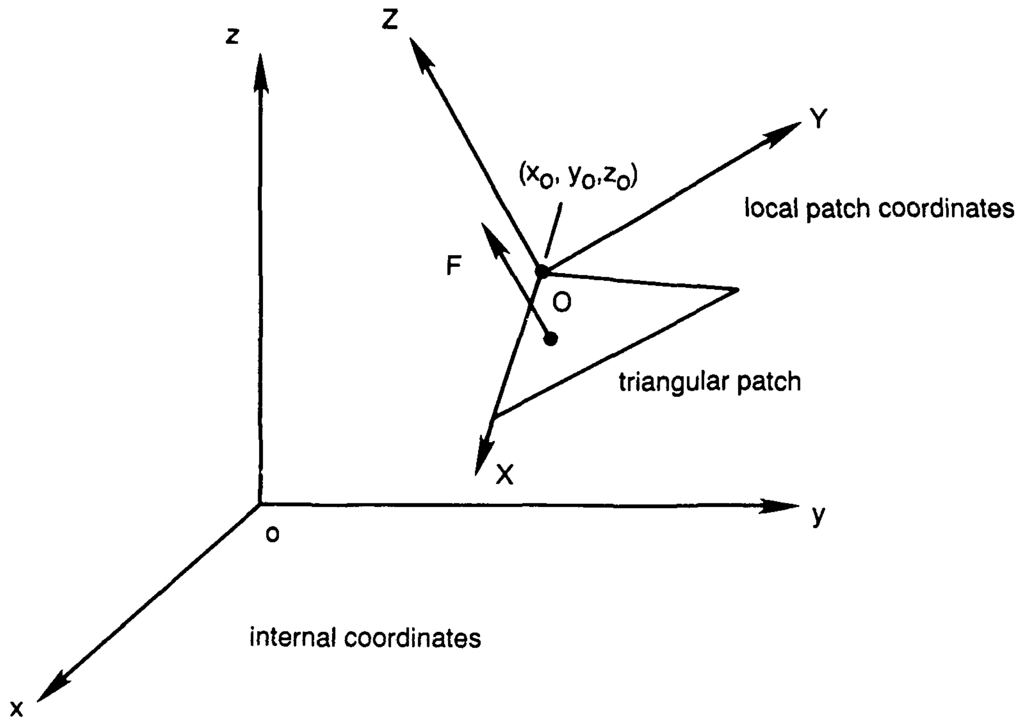


Figure 6.
Transformation of local ship internal global coordinates.

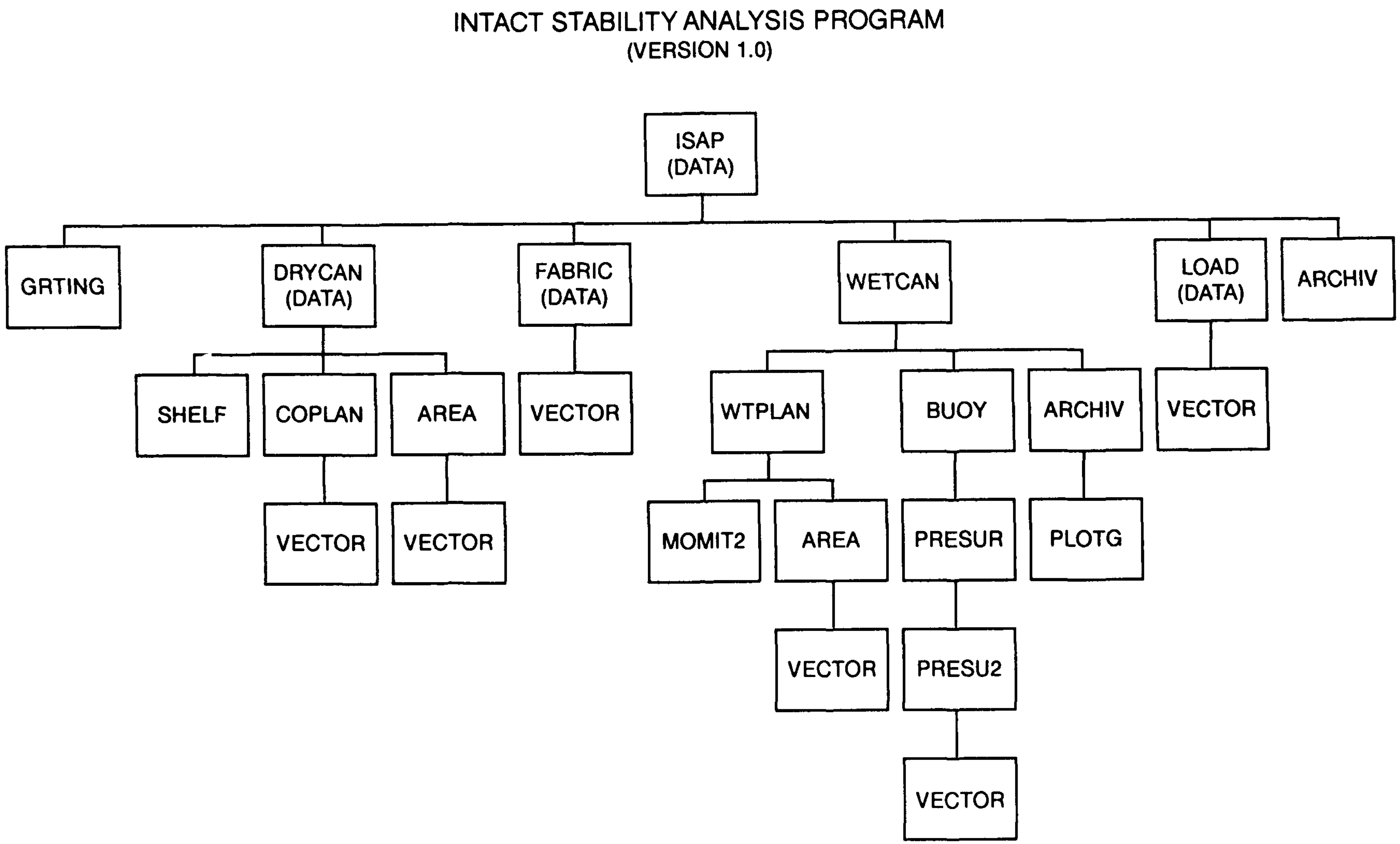


Figure 7.
Program organization.

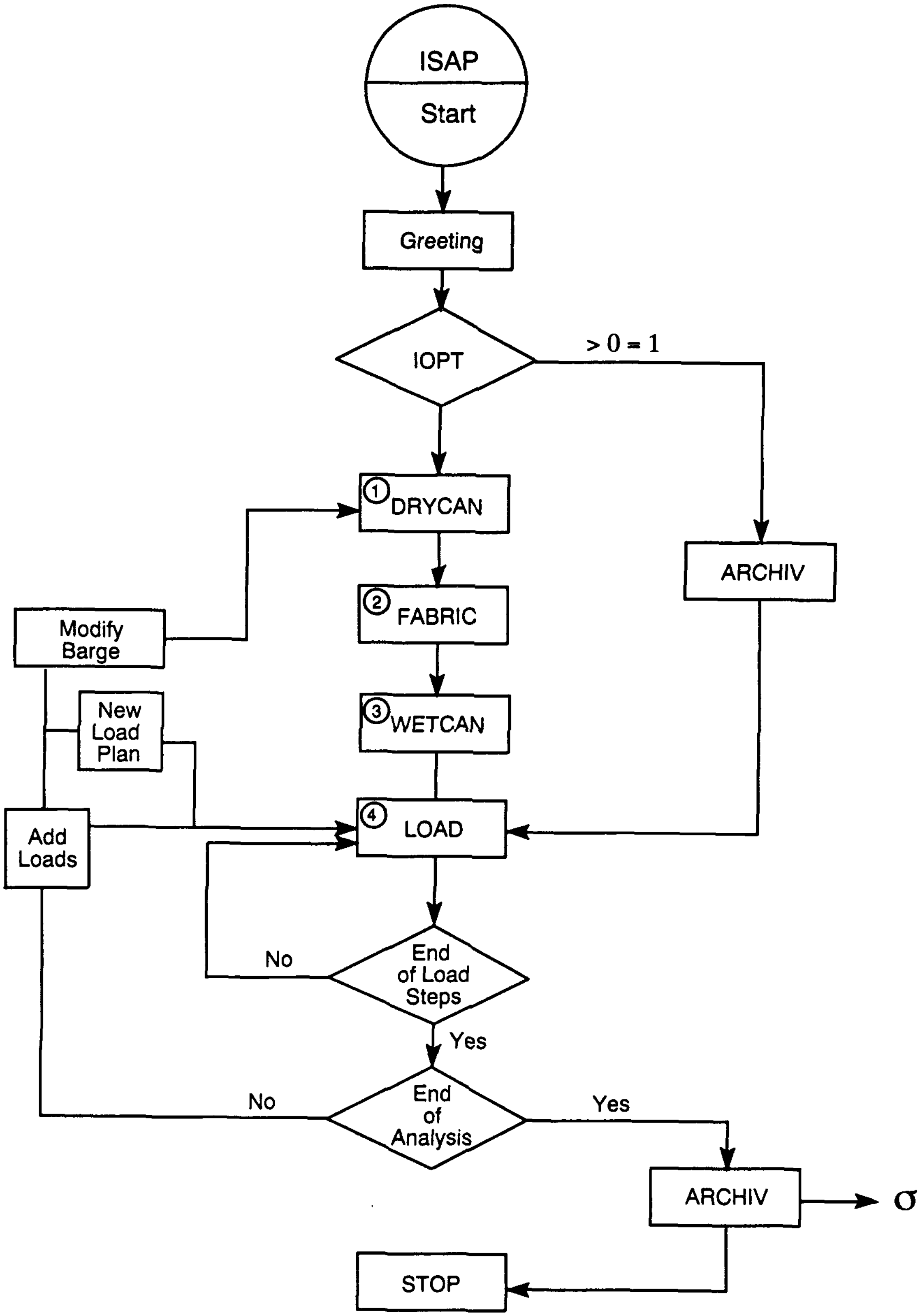


Figure 8.
ISAP flow chart.

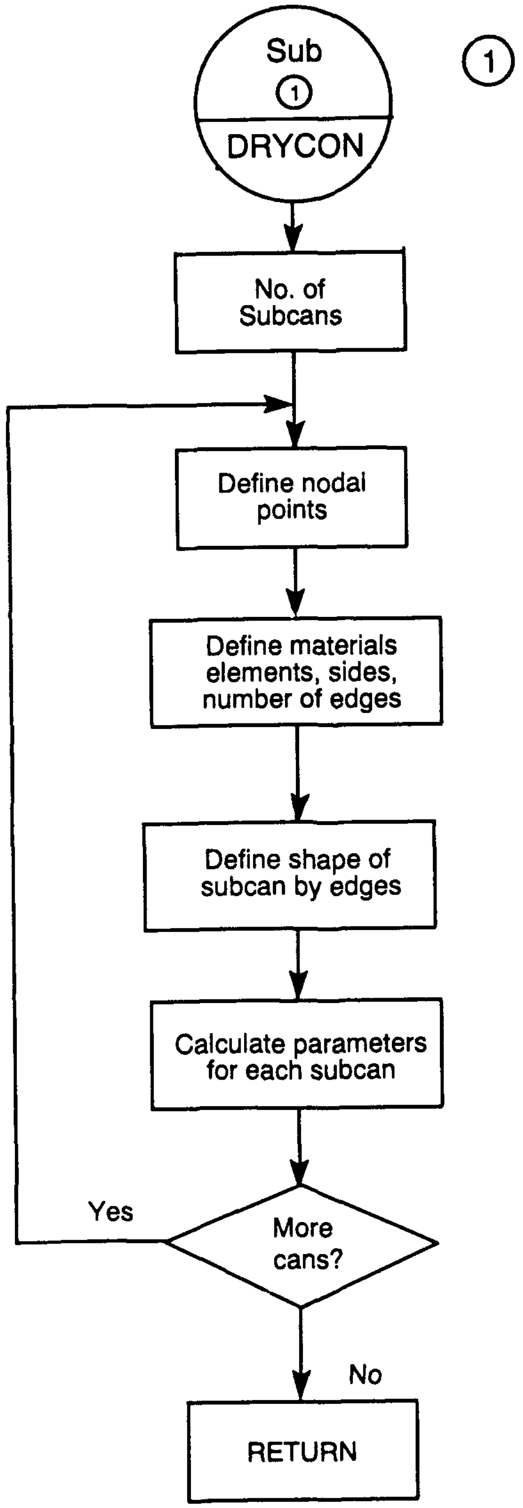


Figure 8.
ISAP flow chart (continued).

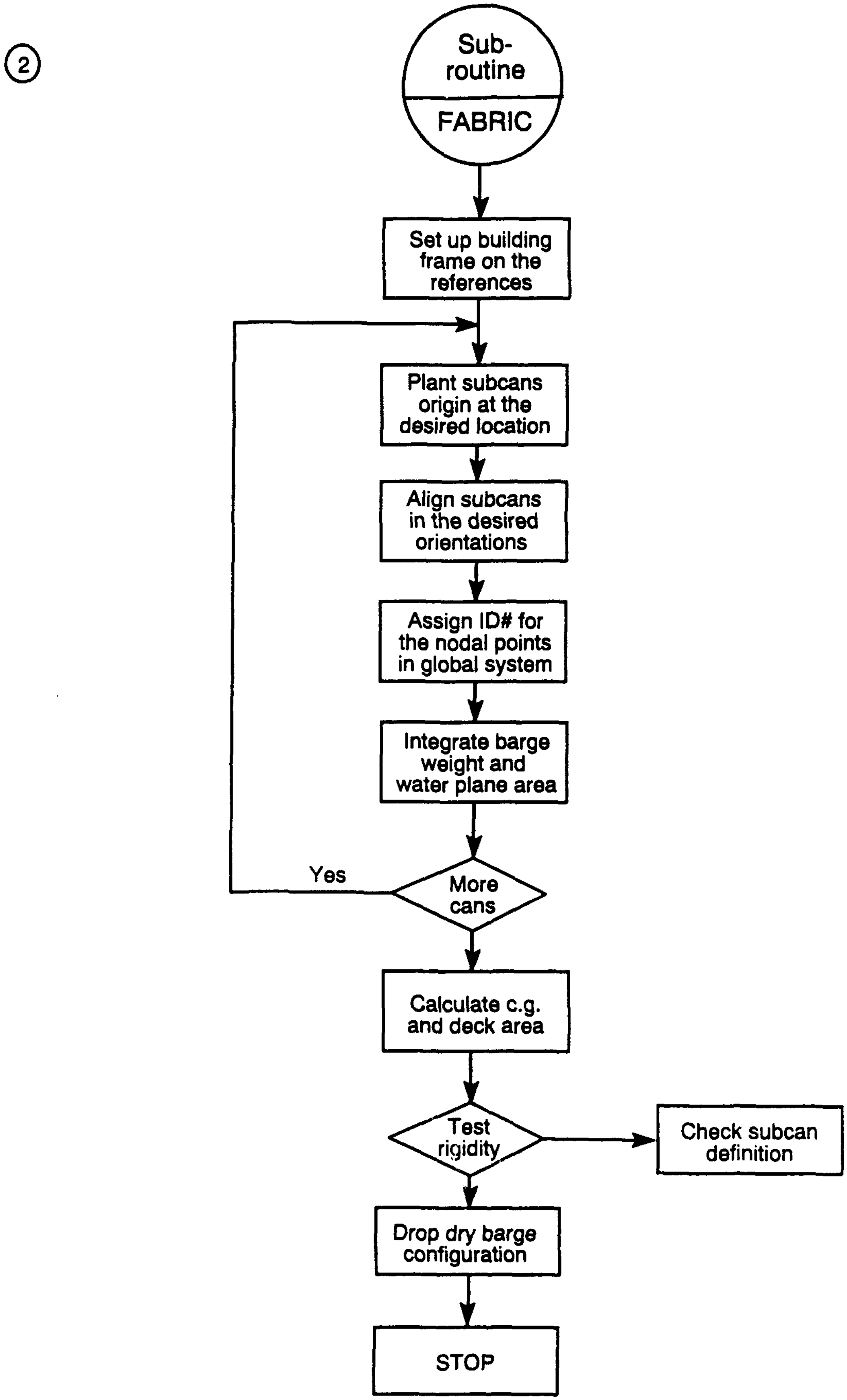


Figure 8.
ISAP flow chart (continued).

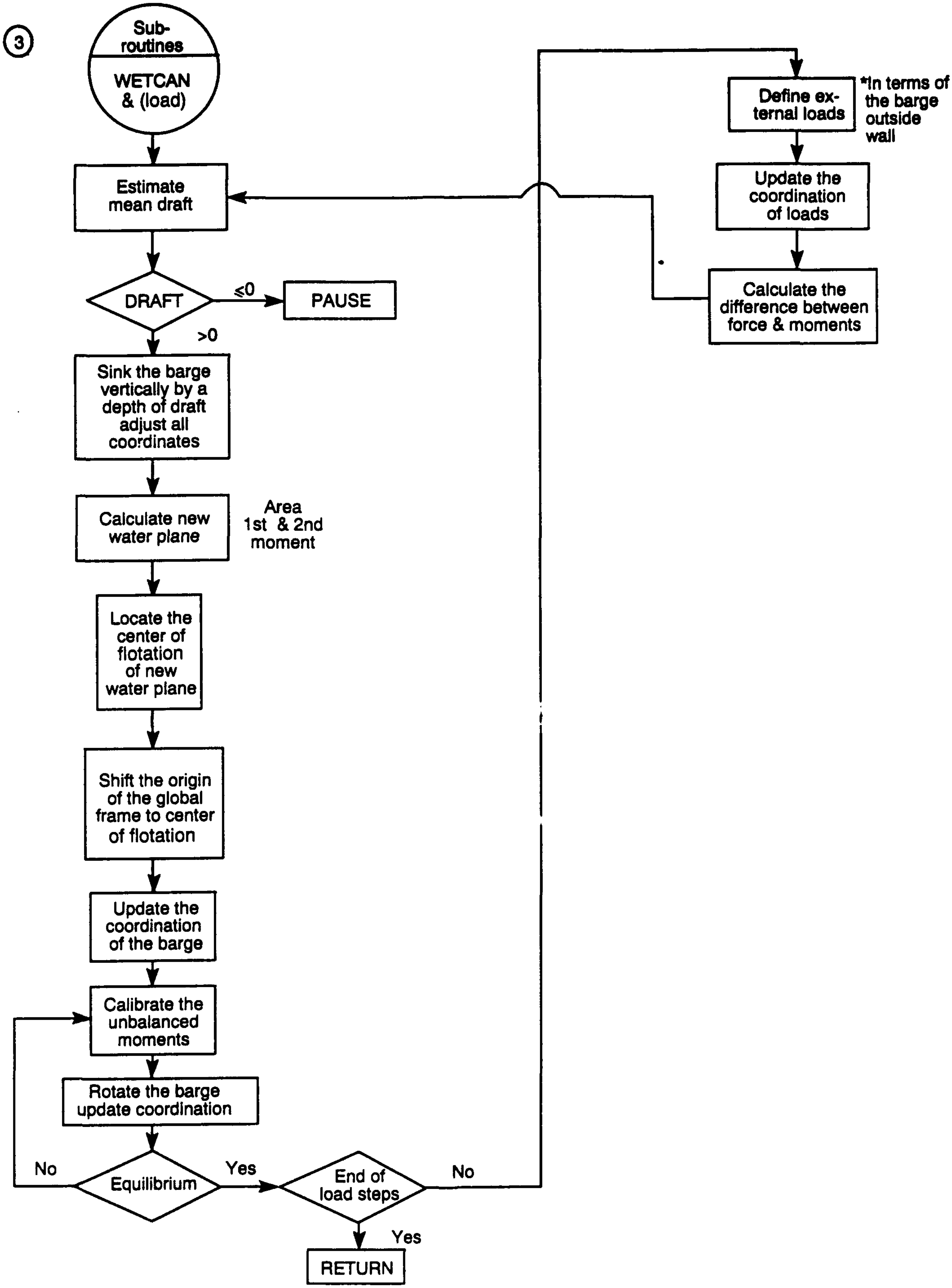


Figure 8.
ISAP flow chart (continued).

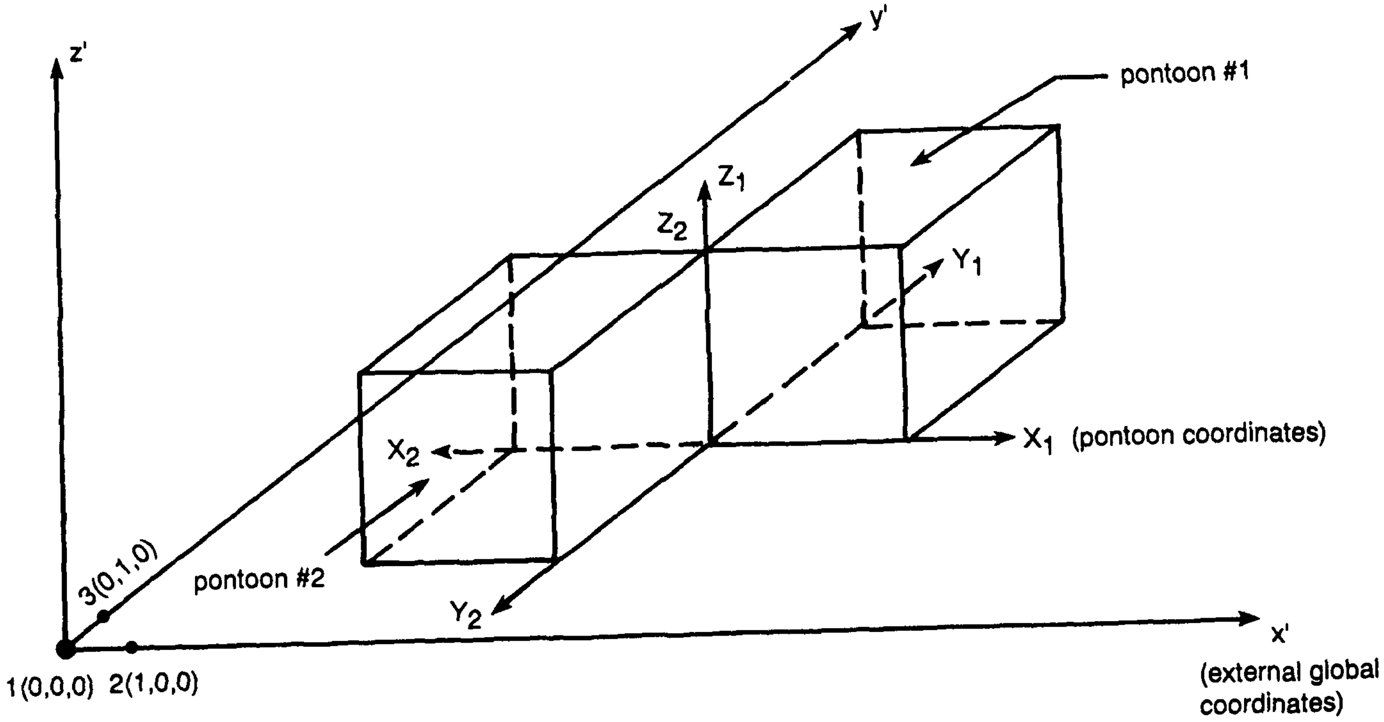


Figure 9.
Procedures for implementing pontoons during barge fabrication.

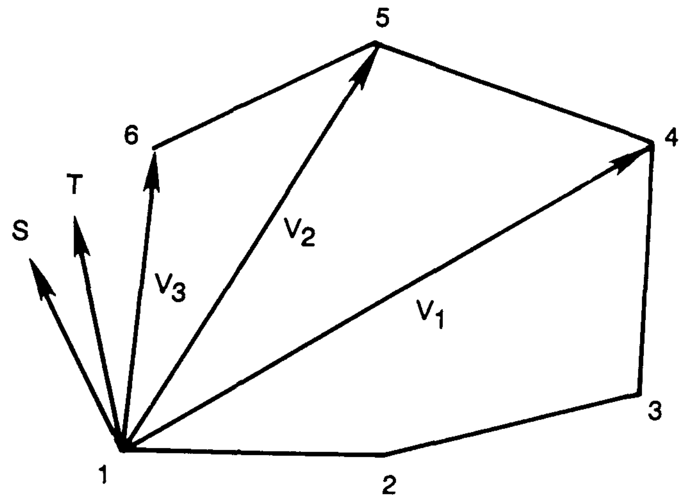


Figure 10.
Definition of a plane element.

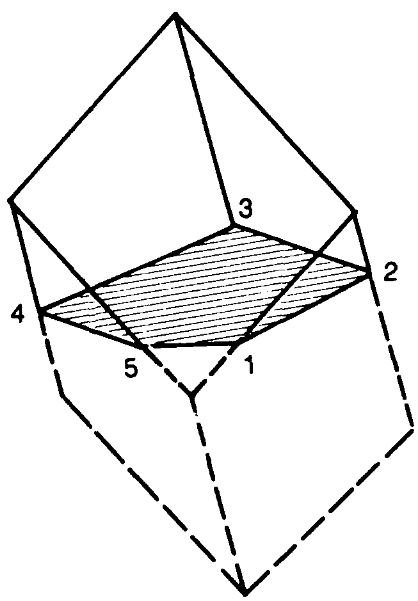


Figure 11.
Water plane area of a pontoon can.

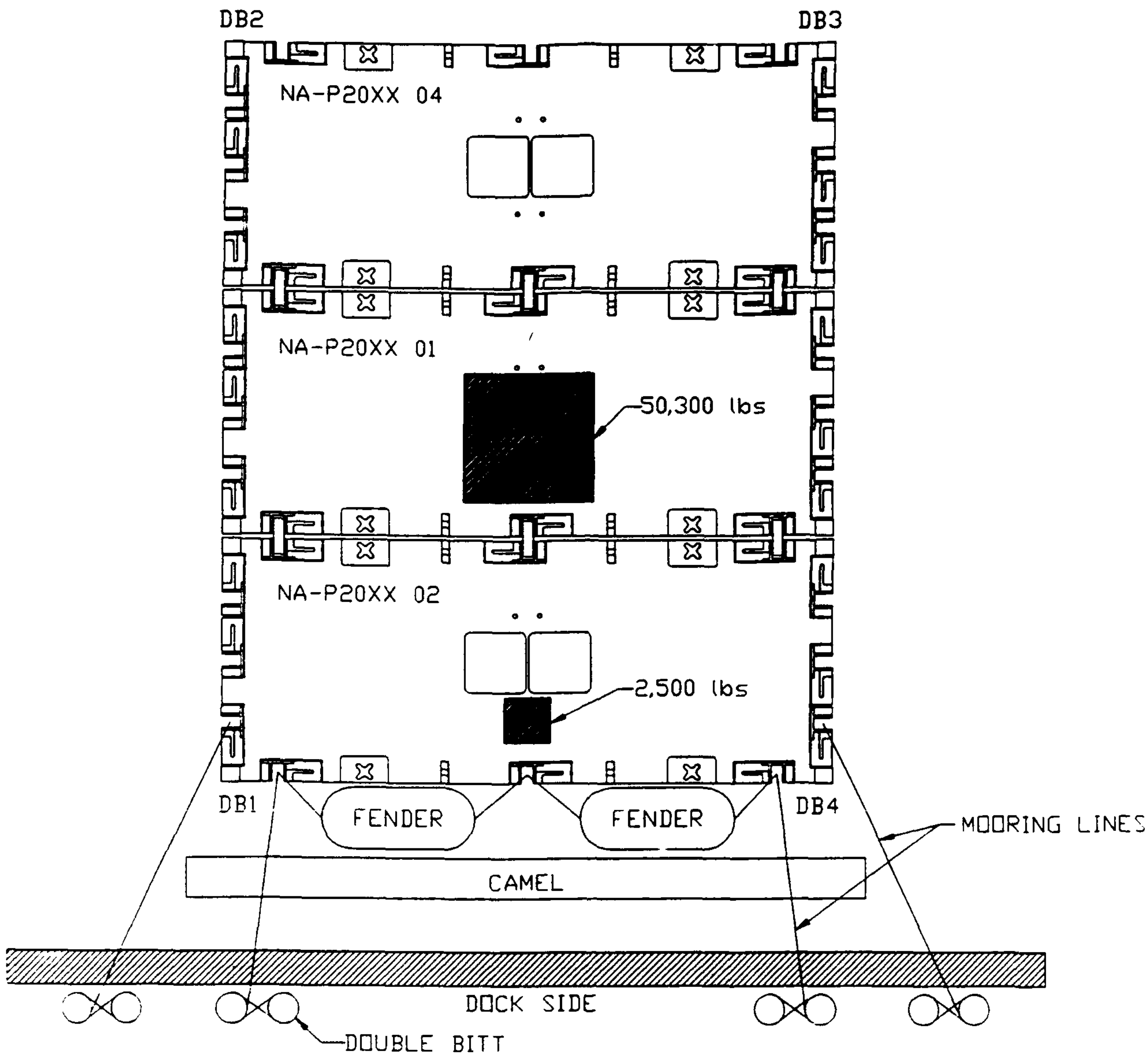


Figure 12.
Full-scale model used for the at-sea test.

Load Configuration	Weights (lb)	Locations
1	Unloaded	--
2	50,300	A
3	50,300 2,500	A B
4	50,300 5,000	A B
5	50,300 10,010	A B
6	50,300 10,010 1,000	A B B

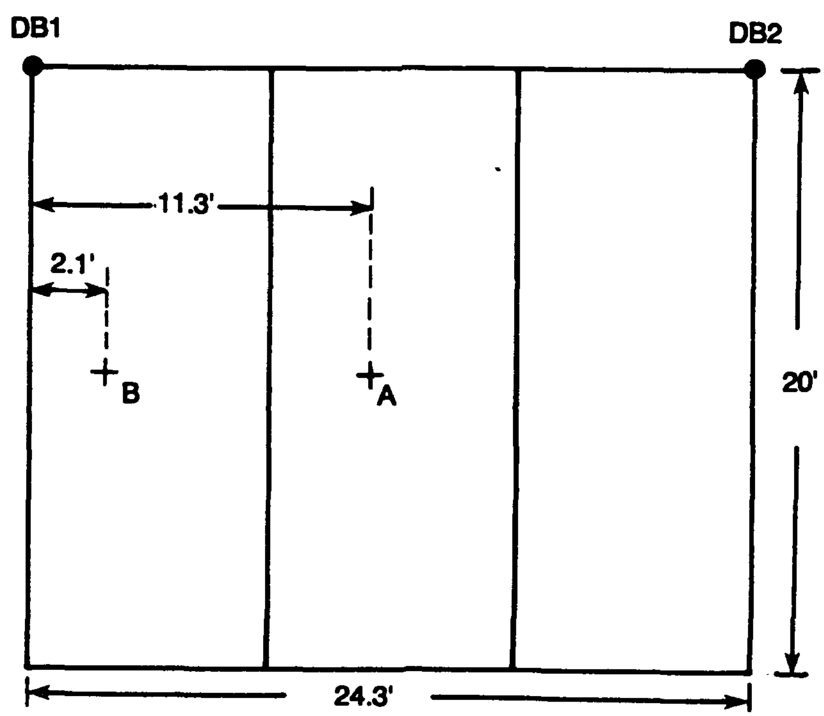


Figure 13.
Load configurations for the at-sea test.

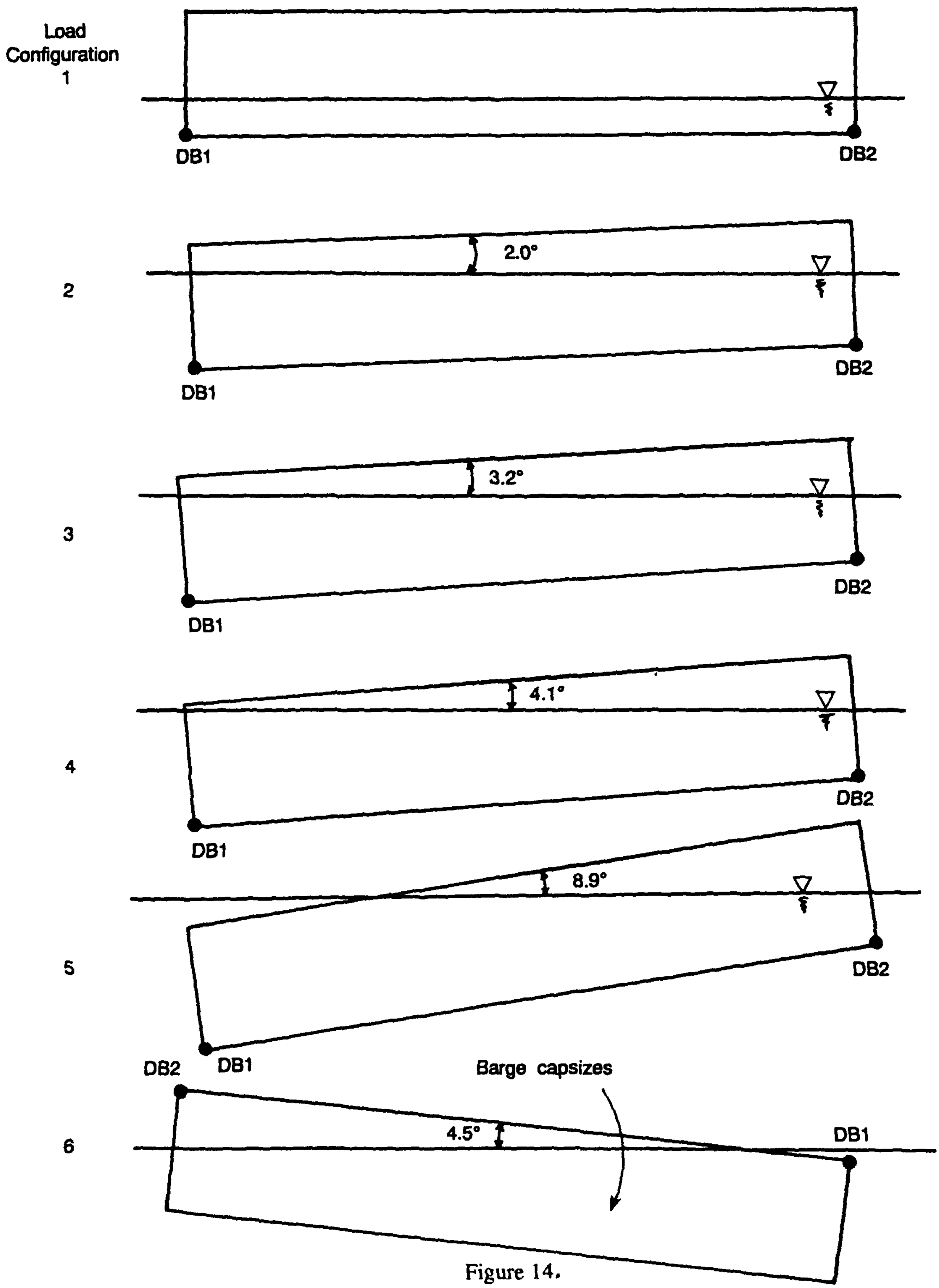


Figure 14.
Barge attitudes under each load configuration.

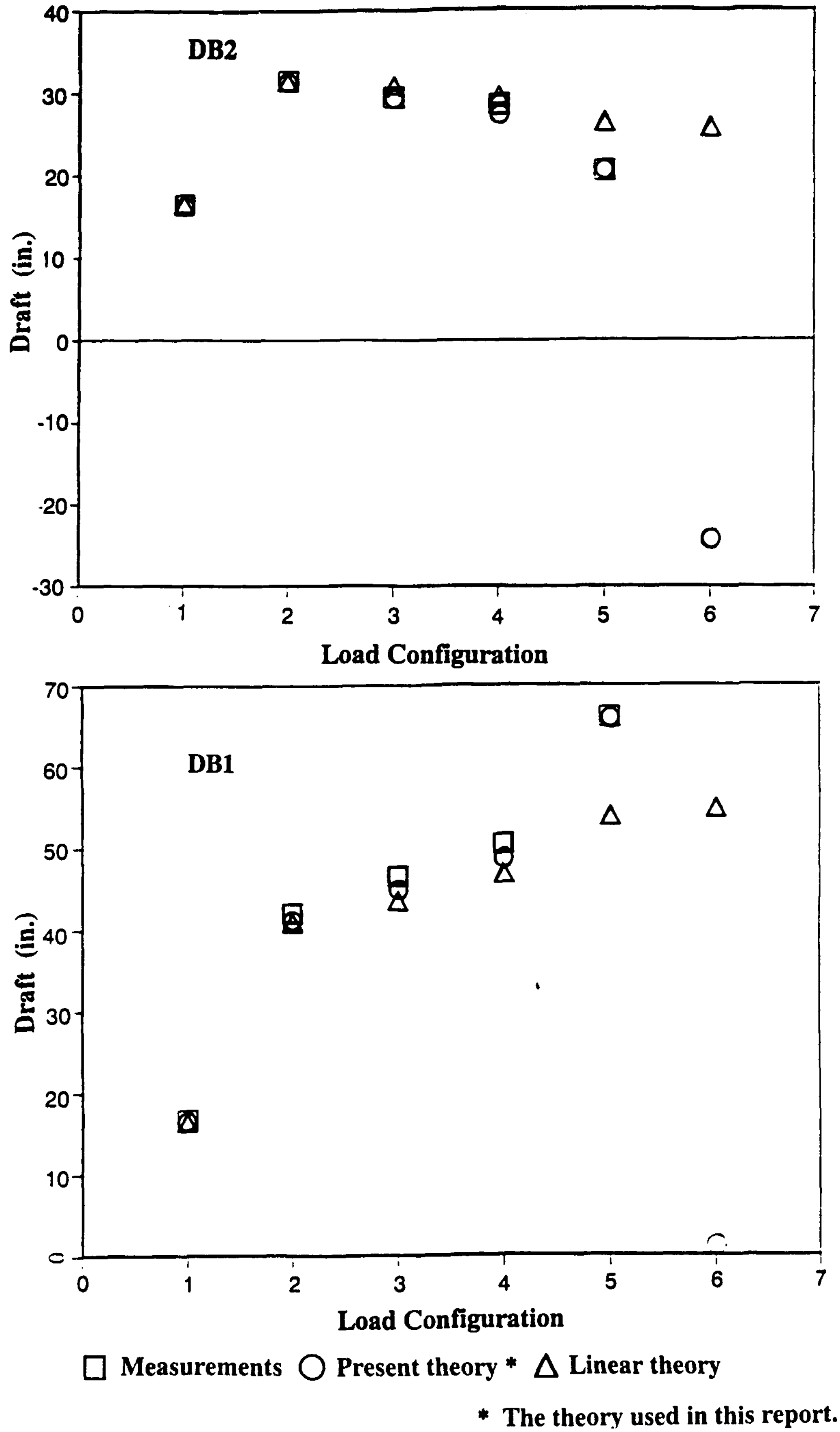


Figure 15.
Comparison of measured drafts with theories.

APPENDIX

USER'S GUIDE TO THE INTACT STABILITY ANALYSIS PROGRAM

SUMMARY

This user's guide provides programming guidance for all ISAP users, regardless of technical background. It discusses the flow of calculations, available options, procedures to prepare input data, and the format of the final results. A most commonly used strategy is provided at the beginning to help users set up an overall analysis plan. This guide leads the users through the program using a practical example. Most of the input prompts are self-explanatory. Sample input and output files are included.

STRATEGY

The program can be executed *in a (pseudo)* batch or interactive mode, or a combination of the two. Executing the program in batch mode is usually more time effective. In this case, the data file must be prepared before execution. Users have a chance to examine the data file for correctness. Once the data file is established, users are able to modify the file for further analysis with minimum effort. This method is recommended for the cases where platform configurations are well defined. However, executing interactively can be more beneficiary to the new user at the stage of exploring platform configurations by trial and error procedure. In the interactive mode, users can explore the program and prepare the input data file by following a series of selfexplanatory prompts on the monitor. Data entries during the interactive mode will be echoed to a user-selected file for future uses in the batch mode. In fact, the users may find it is most convenient to execute the program in the mixed mode. This program will turn the input control back to the user as soon as it hits the "end of file" during execution in batch mode. The user can continue the analysis in the interactive sense. Again, the data entries from here on will be echoed to a user- selected file. The most labor-intensive effort of executing this program is to key in data for the can construction and platform fabrication. Users are, hence, advised to prepare the input data file to the extent of knowledge at that moment, at least through the stage of can construction; then start the analysis in batch, and finish up the sequence interactively. It is always a good idea to build the unique cans and store them on a shelf ahead of time. The detailed procedures for preparing input data files are demonstrated in Figure A-1, which is exactly what the users see on their monitors. All data entries are in free format, which use a single space or comma to separate consecutive data in the same line.

CAN CONSTRUCTION

A greeting frame will flash on the screen as soon as the program is activated and stop at the first prompt, which allows the user to select whether to continue on with the last analysis, or start a new one. For a new job, the program proceeds to build unique cans to be used for platform fabrication. The unique cans will be numbered in the order they are built. Users can pick unique cans that are available on a shelf, or build a new can. Cans may be selected by a number or description. A menu of commonly used can configurations is available from the routine "CANSHELF." The names of the configurations will be displayed on the monitor after the first unsuccessful trial. In case a can is picked from the shelf, the particulars of that can will be echoed to the monitor in the same way that users would enter from the keyboard. To build a new can, the user is requested to respond to each prompt accordingly. Users can refer to the subroutine description of DRYCAN for the requirements and interpretations. Users are requested to estimate the deck area of each unique can. A close estimate will slightly expedite the search for light platform equilibrium positions. The new can may be added to the can shelf if necessary. The sample input file illustrates both options by selecting a predefined can ISO 20 from the shelf and creating a new can, ISO 20 RAKED, manually.

PLATFORM FABRICATION

The program is ready to have the user design a platform as soon as all unique cans are selected or built. Again, this is driven by a series of self-explanatory prompts. Basically, the constituent cans are implemented by inserting the origins of can coordinates at the desired locations specified in the external global coordinates, and aligning the lateral axis in the desired directions, see Figure 9. The direction is specified by a pair of reference points in the external global coordinates, which indicates a vector leading from the first reference point to the second. The program is implemented with three default reference points, which are located at (0,0,0), (1,0,0), and (0,1,0), for reference points 1, 2, and 3, respectively. The pair of reference points (1, 2) define the direction along the x-axis, for example. Users can define up to 10 reference points for a more complicated pontoon. All cans are assumed to be rigidly connected to one another. The effort of platform fabrication is done in Subroutine FABRIC.

LAUNCH

The light platform is then automatically "launched" without further instruction. It will find its equilibrium position and print the results on the monitor for inspection. Since the platform can rotate a large angle in any way, its draft, heel angle, and trim angle are not as well defined as those of a ship (please refer to "Definitions" for their definitions). The platform is now ready for receiving cargo. Users can also select to modify the platform configuration or begin the loading tests. This procedure is done in Subroutine WETCAN.

LOADS

Cargo can be placed in any number in any order as required. Weight is assumed to apply at the center of each piece of cargo. The vertical height of the weight plays an important role, especially when the platform rotates with large trim or heel angles. The center of gravity for each cargo must be estimated as close as possible. The program will find the new equilibrium position after each loading step and print the results on the monitor. Analysis can be continued for the rest of the loading plan in the same manner. Removing cargo can be done by adding a negative force of the same amount at the location of the cargo to be removed. At the end of each loading step, users have the choice of: (1) adding more loads, (2) starting a new load plan, (3) returning to the platform fabrication stage to modify the platform design, and (4) terminating the analysis procedure. The load analysis is conducted in Subroutine LOAD.

EXAMPLE

Inputs

This example illustrates the detailed procedure of using ISAP through a case study of a pontoon barge subjected to deck cargo. The barge under study consists of nine ISO pontoons arranged in a two- dimensional array of three sections wide by three sections long as shown in Figure A-2. All pontoons are rigidly connected. The three pontoons in the middle are rectangular box shape, whereas the other six are tapered to give the raked bow and stern shape. These two pontoon types will be referred as "ISO 20" and "ISO 20 RAKED" pontoons, respectively. Their principal dimensions are given in Figures A-3 and A-4. A series of cargoes will be placed on the barge as shown in Figure A-2 to study the barge responses. The numbers in parenthesis indicate the load steps.

The detailed procedures will be demonstrated and explained in the interactive mode, in which users enter all the input data. Figure A-1 shows a screen image that users would actually see on their monitors if the batch mode option is selected. The output file, which remains the same for both options, is illustrated in Figure A-5.

As soon as the program is called, the program flashes a greeting frame and stop at the first prompt

```
Enter 0=new job    , 1=continuation job     :
```

The user can select "0" to start a new analysis from scratch, or "1" to resume the previous analysis from where it was terminated. In this sample, we enter "0". The program proceeds to the next prompt:

```
Enter input file name or "RETURN" if enter data from keyboard:
```

Entering a data file name here will force the program to read the input data for the following steps up to the end of that data file before returning the control back to the user. The data file must be prepared in the same order as if they were entered from the keyboard in advance. A

sample input data file, including a line-by-line interpretation, is shown in Figure A-6. For this illustration, we will hit the carriage return to continue. The program stops at:

```
Enter total number of unique can types     :
```

The user enters the number of unique cans for fabricating the barge, which is "2" in our case. The program is now ready to construct the first unique can by displaying the following prompts. User can either pick a can from the shelf by selecting the "Old" option, or construct a new can by selecting the "New" option. We will demonstrate both options by picking the first can from the shelf and constructing the second can manually. A sample can shelf used for this demonstration is presented in Figure A-7. Figures A-3, A-4, and A-8 give the dimensions of these pontoons.

```
*** CONSTRUCTING UNIQUE CAN TYPE  1
New/Old?            : Old

Enter a menu number OR name :  ISO 20
```

"ISO 20" is the name of the first unique can as stored on the shelf. The program will search through the shelf for the details of that can. The information will be echoed to the monitor in the same way as they were entered from the keyboard. The program will then stop at the input prompts for the second unique can.

```
*** CONSTRUCTING UNIQUE CAN TYPE  2
New/Old?            : NEW
```

The selection of the "NEW" option will cause the program to prompt for can information as follows.

```
Enter a menu number OR name :  RAKE END 20
```

The user must provide a name for the unique can to be constructed. The can may be stored on the shelf for future use. The can is constructed in a similar manner as that normally used to define a finite element model. All locations are specified in a right-hand cartesian system. Users are referred to the description of the Subroutine "DRYCAN" as well as Figure 3 for the coordinate convention and the definitions of the nodes, edges, and elements. The program will prompt in sequence for the coordinates of all nodes to be used for placing the building materials as follows.

```
Number of nodes per can?        :  10
Enter coordinates of first node :   0.0     0.0     0.0
Enter coordinates of next node  :  17.0     0.0     0.0
                                .
                                .
                                .
Enter coordinates of next node  :  20.0     8.0     3.0
```

Next, users are ready to define all material to be used for can construction, which includes plates, beams, or point weights. The materials are specified by their unit weights in pounds, e.g., lb/sq ft, lb/ft, or lb, etc. This example uses plates only.

```
Number of materials in can?        :  1
Enter thickness of first material  :  22.5
```

The user can begin to construct the can by placing the selected material over the nodes specified by the node numbers. The vertexes of a plate must be specified in the counterclockwise direction looking from outside of the floats.

```
Number of elements in subcan?                        :  7
For each element, enter the following:
Material type, # of vertices, ID # of each vertex   :  1 4 4 3 2 1
Material type, # of vertices, ID # of each vertex   :  1 4 5 6 7 8
                                   .
                                   .
                                   .
```

Users must also specify the exterior edges of the can, each by a pair of node numbers at the ends.

```
Enter number of edges in can  :  15
For each edge, enter the following:
ID # of node points  :  1    2
ID # of node points  :  2    3
                     .
                     .
                     .
ID # of node points  :  9    10
```

Users are also requested to make a rough estimate of the deck area of the can in an upright attitude.

```
   Enter approximate deck area  :  146.0
   ------------------------------------------------------
```

This concludes the process of can construction. A list of available cans on the active shelf will be displayed on the monitor at this point.

```
                  ** Available Shelf Can Types **

               1      ISO 20
               2      ISO 40
               3      RAKE END 20
               4      ISO 30
               5      ISO 301
```

The user can decide whether or not to add the can just constructed to the list. We chose not to do so, because this particular can already exists.

```
*** Add can type to file shelf& (Y/N)  :  N
```

Now, we have defined all the unique cans to be used. We are ready to construct the barge using these cans. This will be done by implementing the origins of cans at the desired locations and arranging the local axes of the cans in the desired directions. The nodes and other features of the cans will be implemented accordingly. The locations and directions are referred to an external coordinate system attached to the barge, which will be called "fabrication coordinate system." Several reference nodes are required for specifying the orientation of cans. The user can use the default reference nodes, or specify their own to fit the geometry of floating structures. The same coordinaté system will also be used to specify and trace deck loads. All values specified in the coordinate remain unchanged throughout the analysis. The actual procedures are illustrated as follows. This example uses the default option.

```
*****   BARGE FABRICATION SECTION   *****
Subcan reference point orientation 0-10,
0 = default right-hand cartesian system  :  0
Enter total number of subcans in barge   :  9
For each subcan, enter the following:
----------------------------------------
Can type, origin, and axis orientation  :  1  0.0  0.0  0.0 1 2 1 3
Can type, origin, and axis orientation  :  1  0.0  8.0  0.0 1 2 1 3
Can type, origin, and axis orientation  :  1  0.0 16.0  0.0 1 2 1 3
                                        .
                                        .
                                        .
Can type, origin, and axis orientation  :  2  0.0 24.0  0.0 2 1 3 1
-------------------------------------------------------------------
```

When the barge fabrication is completed, the program automatically launches the barge and finds its lightweight attitude. The basic parameters of the barge attitude will be echoed to the monitor. Users are ready to place the deck loads at this point.

```
        <<<<< LAUNCH >>>>>


WETCAN:  Equilibrium shape of the barge.
Approximate draft    =    1.33 feet,
heel angle (roll)    =    0.00 degrees,
trim angle (pitch)   =    0.00 degrees.

-------------------
```

Deck loads can be placed in steps. Each step can consist of any number of loads with a limit of 100 loads for the entire loading configuration. The loading condition to date and the resulting barge attitude will be displayed on the monitor. The program will then pause at a decision point pending instruction from the user. The user can continue the current load analysis (Option 1), return to the lightweight condition and start off a new loading plan (Option 2), return to the barge fabrication stage to modify the barge shape (Option 3), or conclude the analysis (Option 4). This example goes through eight loading steps. Load step 9 illustrates another variation that occurs when the data entry are made from an existing file. In that case, the program will turn the control back to the keyboard, as soon as the end-of-file mark of the data file is reached.

```
     *****   EXTERNAL LOADS SECTION    *****
     Enter number of cargo weights    :  1
     For each weight load enter the following:
     -----------------------------------------
     Weight, and global coordinates  :  20000.0   10.0   12.0   4.5
     -------------------------------------------------------------
     <<<<< LOAD STEP  1 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft     =   1.56 feet,
     heel angle (roll)     =   0.00 degrees,
     trim angle (pitch)    =   0.00 degrees.


Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:  1

     *****   EXTERNAL LOADS SECTION    *****
     Enter number of cargo weights    :  1
     For each weight load enter the following:
     -----------------------------------------
     Weight, and global coordinates  : -10000.0   10.0   12.0   4.5
     -------------------------------------------------------------
     <<<<< LOAD STEP  2 >>>>>

     WETCAN: Equilibrium shape of the barge.
     Approximate draft     =   1.44 feet,
     heel angle (roll)     =   0.00 degrees,
     trim angle (pitch)    =   0.00 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit: 1
                                     .
                                     .
                                     .
```

```
     *****   EXTERNAL LOADS SECTION    *****
     Enter number of cargo weights     :  2
     For each weight load enter the following:
     ------------------------------------------
     Weight, and global coordinates    :  10000.0   30.0   24.0   4.5
     Weight, and global coordinates    : -10000.0  -10.0    0.0   4.5
     ------------------------------------------------------------------
     <<<<< LOAD STEP  8 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft   =   3.61 feet,
     heel angle (roll)   =  -3.53 degrees,
     trim angle (pitch)  =  -0.44 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit: 1

     ---------------------------------------------
     *****   EXTERNAL LOADS SECTION    *****
     Enter number of cargo weights     :

     ****   End of data in input file    ***
     Hit <return> to continue, enter data from keyboard,
     Data entry will be saved in a user specified file.

     Enter number of cargo weights     :1
     1
     For each weight load enter the following:
     ------------------------------------------
     Weight, and global coordinates    :10000. 0. 00. 0.
     10000.0    0.0    0.0    0.0
     -----------------------------------------------------
     <<<<< LOAD STEP  9 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft    =    3.45 feet,
     heel angle (roll)    =   -1.75 degrees,
     trim angle (pitch)   =   -0.65 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:  4

    **** STOP
```

Outputs

The results of analysis are displayed on the monitor in a compact format as shown in the screen image (Figure A-5). The same information is also echoed to a output file "OUTPUT," which also keeps track of other major activities occurring throughout the analysis, including the basic information of each unique can selected and the barge fabrication procedures. Also provided in the output file is the locations of all nodes (in the internal coordinate system), which describe the exact attitude of the barge at that moment. The frame is generated mainly for graphical display purpose.

```
**************************************************************
*                        WELCOME TO                          *
*                                                            *
*                        I S A P !                           *
*                                                            *
*                                                            *
*          an Intact Stability Analysis Program              *
*          for the floating pontoon structures.              *
*                                                            *
*              Version 1.1, 23 February, 1990                *
*                                                            *
*                   Erick T. Huang, PhD                      *
*              Naval Civil Engineering Laboratory            *
*                  Port Hueneme, CA  93043                   *
*          Tel. (805) 982-1256, or  A/V  551-1256.           *
**************************************************************


 ** To choose defaults when listed, press RETURN **
--------------------------------------------------------------------------------
 *****   GENERAL PROGRAM PARAMETERS   *****
Enter 0=new job    , 1=continuation job     : 0
--------------------------------------------------------------------------------
Enter input file name or "RETURN" if enter data from keyboard: <ENTER>
 *****   UNIQUE CAN TYPES SECTION   *****
Enter total number of unique can types        :   2
 *** CONSTRUCTING UNIQUE CAN TYPE  1
New/Old?          : OLD

--------------------------------------------------------------------------------
Enter a menu number OR name :  ISO 20
***** Search can type   1 from SHELF.
Number of nodes per can?          :    8
Enter coordinates of first node   :    0.0    0.0    0.0
Enter coordinates of next node    :   20.0    0.0    0.0
Enter coordinates of next node    :   20.0    8.0    0.0
Enter coordinates of next node    :    0.0    8.0    0.0
Enter coordinates of next node    :    0.0    0.0    4.5
Enter coordinates of next node    :   20.0    0.0    4.5
Enter coordinates of next node    :   20.0    8.0    4.5
Enter coordinates of next node    :    0.0    8.0    4.5
---------------------------------------
Number of materials in can?            :   1
Enter thickness of first material      :    22.7
Number of elements in subcan?          :   6
For each element, enter the following:
---------------------------------------
Material type, # of vertices, ID # of each vertex:   1   4   4   3   2   1
Material type, # of vertices, ID # of each vertex:   1   4   5   6   7   8
Material type, # of vertices, ID # of each vertex:   1   4   1   5   8   4
Material type, # of vertices, ID # of each vertex:   1   4   2   3   7   6
Material type, # of vertices, ID # of each vertex:   1   4   1   2   6   5
```

Figure A-1.
Screen image of sample run for the 3 by 3 pontoon barge analysis.

```
Material type, # of vertices, ID # of each vertex:   1   4   3   4   8   7
---------------------------------------
Enter number of edges in can  :  12
For each edge, enter the following:
---------------------------------------
ID # of node points   :     1    2
ID # of node points   :     2    3
ID # of node points   :     3    4
ID # of node points   :     4    1
ID # of node points   :     5    6
ID # of node points   :     6    7
ID # of node points   :     7    8
ID # of node points   :     8    5
ID # of node points   :     1    5
ID # of node points   :     4    8
ID # of node points   :     2    6
ID # of node points   :     3    7
---------------------------------------
Enter approximate deck area      :   160.0
 *** CONSTRUCTING UNIQUE CAN TYPE  2
New/Old?          : NEW
Enter a menu number OR name :  RAKE END 20
Number of nodes per can?            :    10
Enter coordinates of first node     :    0.0    0.0    0.0
Enter coordinates of next node      :   17.0    0.0    0.0
Enter coordinates of next node      :   17.0    8.0    0.0
Enter coordinates of next node      :    0.0    8.0    0.0
Enter coordinates of next node      :    0.0    0.0    4.5
Enter coordinates of next node      :   20.0    0.0    4.5
Enter coordinates of next node      :   20.0    8.0    4.5
Enter coordinates of next node      :    0.0    8.0    4.5
Enter coordinates of next node      :   20.0    0.0    3.0
Enter coordinates of next node      :   20.0    8.0    3.0
---------------------------------------
Number of materials in can?              :   1
Enter thickness of first material        :    22.5
Number of elements in subcan?            :   7
For each element, enter the following:
---------------------------------------
Material type, # of vertices, ID # of each vertex:   1   4   4   3   2   1
Material type, # of vertices, ID # of each vertex:   1   4   5   6   7   8
Material type, # of vertices, ID # of each vertex:   1   4   1   5   8   4
Material type, # of vertices, ID # of each vertex:   1   4   2   3  10   9
Material type, # of vertices, ID # of each vertex:   1   4   9  10   7   6
Material type, # of vertices, ID # of each vertex:   1   5   1   2   9   6   5
Material type, # of vertices, ID # of each vertex:   1   5   3   4   8   7  10
---------------------------------------
Enter number of edges in can  :  15
For each edge, enter the following:
---------------------------------------
ID # of node points   :     1    2
ID # of node points   :     2    3
ID # of node points   :     3    4
ID # of node points   :     4    1
ID # of node points   :     5    6
ID # of node points   :     6    7
ID # of node points   :     7    8
ID # of node points   :     8    5
ID # of node points   :     1    5
ID # of node points   :     4    8
```

Figure A-1.(Continued)

```
ID # of node points   :    2    9
ID # of node points   :    9    6
ID # of node points   :    3   10
ID # of node points   :   10    7
ID # of node points   :    9   10
---------------------------------------
Enter approximate deck area     :   146.0
------------------------------------------------------------------------------
    ** Available Shelf Can Types **


  1     ISO 20
  2     ISO 40
  3     RAKE END 20
  4     ISO 30
  5     ISO 301
  6     ISO 301
------------------------------------------------------------------------------
 *** Add can type to file shelf? (Y/N)  :
------------------------------------------------------------------------------
 *****   BARGE FABRICATION SECTION   *****
Subcan reference point orientation 0-10,
0 = default right-hand cartesian system  :   0
Enter total number of subcans in barge   :   9
For each subcan, enter the following:
---------------------------------------
Can type, origin, and axis orientation :  1    0.0    0.0    0.0  1  2  1  3
Can type, origin, and axis orientation :  1    0.0    8.0    0.0  1  2  1  3
Can type, origin, and axis orientation :  1    0.0   16.0    0.0  1  2  1  3
Can type, origin, and axis orientation :  2   20.0    0.0    0.0  1  2  1  3
Can type, origin, and axis orientation :  2   20.0    8.0    0.0  1  2  1  3
Can type, origin, and axis orientation :  2   20.0   16.0    0.0  1  2  1  3
Can type, origin, and axis orientation :  2    0.0    8.0    0.0  2  1  3  1
Can type, origin, and axis orientation :  2    0.0   16.0    0.0  2  1  3  1
Can type, origin, and axis orientation :  2    0.0   24.0    0.0  2  1  3  1
------------------------------------------------------------------------------
  <<<<< LAUNCH >>>>>


      WETCAN: Equilibrium shape of the barge.
      Approximate draft  =    1.33 feet,
      heel angle (roll)    =    0.00 degrees,
      trim angle (pitch)   =    0.00 degrees.

------------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION   *****
Enter number of cargo weights     :  1
For each weight load enter the following:
---------------------------------------
Weight, and global coordinates    : 20000.0   10.0   12.0   4.5
------------------------------------------------------------------------------
  <<<<< LOAD STEP  1 >>>>>


      WETCAN: Equilibrium shape of the barge.
      Approximate draft  =    1.56 feet,
      heel angle (roll)    =    0.00 degrees,
      trim angle (pitch)   =    0.00 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
```

Figure A-1.(Continued)

```
--------------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION   *****
Enter number of cargo weights       :  1
For each weight load enter the following:
----------------------------------------
Weight, and global coordinates     :-10000.0   10.0   12.0    4.5
--------------------------------------------------------------------------------
  <<<<< LOAD STEP  2 >>>>>


      WETCAN: Equilibrium shape of the barge.
      Approximate draft  =     1.44 feet,
      heel angle (roll)    =     0.00 degrees,
      trim angle (pitch)   =     0.00 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
--------------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION   *****
Enter number of cargo weights       :  2
For each weight load enter the following:
----------------------------------------
Weight, and global coordinates     :  5000.0   10.0    0.0    4.5
Weight, and global coordinates     :  5000.0   10.0   24.0    4.5
--------------------------------------------------------------------------------
  <<<<< LOAD STEP  3 >>>>>


      WETCAN: Equilibrium shape of the barge.
      Approximate draft  =     1.56 feet,
      heel angle (roll)    =     0.00 degrees,
      trim angle (pitch)   =     0.00 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
--------------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION   *****
Enter number of cargo weights       :  1
For each weight load enter the following:
----------------------------------------
Weight, and global coordinates     : 10000.0  -20.0   12.0    4.5
--------------------------------------------------------------------------------
  <<<<< LOAD STEP  4 >>>>>


      WETCAN: Equilibrium shape of the barge.
      Approximate draft  =     2.01 feet,
      heel angle (roll)    =     0.00 degrees,
      trim angle (pitch)   =    -0.72 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
--------------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION   *****
Enter number of cargo weights       :  1
For each weight load enter the following:
----------------------------------------
Weight, and global coordinates     : 10000.0   40.0   12.0    4.5
--------------------------------------------------------------------------------
  <<<<< LOAD STEP  5 >>>>>


      WETCAN: Equilibrium shape of the barge.
```

Figure A-1.(Continued)

```
     Approximate draft  =     1.79 feet,
     heel angle (roll)     =     0.00 degrees,
     trim angle (pitch)    =     0.00 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
----------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION    *****
Enter number of cargo weights      :  3
For each weight load enter the following:
-------------------------------------
Weight, and global coordinates     : 10000.0    20.0     8.0     4.5
Weight, and global coordinates     : 10000.0    20.0    16.0     4.5
Weight, and global coordinates     : 10000.0    30.0    12.0     4.5
----------------------------------------------------------------------------
  <<<<< LOAD STEP  6 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft  =     2.55 feet,
     heel angle (roll)     =     0.00 degrees,
     trim angle (pitch)    =     0.92 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
----------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION    *****
Enter number of cargo weights      :  1
For each weight load enter the following:
-------------------------------------
Weight, and global coordinates     : 50000.0   -10.0    12.0     4.5
----------------------------------------------------------------------------
  <<<<< LOAD STEP  7 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft  =     3.29 feet,
     heel angle (roll)     =     0.00 degrees,
     trim angle (pitch)    =    -1.31 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
----------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION    *****
Enter number of cargo weights      :  2
For each weight load enter the following:
-------------------------------------
Weight, and global coordinates     : 10000.0    30.0    24.0     4.5
Weight, and global coordinates     :-10000.0   -10.0     0.0     4.5
----------------------------------------------------------------------------
  <<<<< LOAD STEP  8 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft  =     3.61 feet,
     heel angle (roll)     =    -3.53 degrees,
     trim angle (pitch)    =    -0.44 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:
----------------------------------------------------------------------------
 *****   EXTERNAL LOADS SECTION    *****
Enter number of cargo weights      :
```

Figure A-1.(Continued)

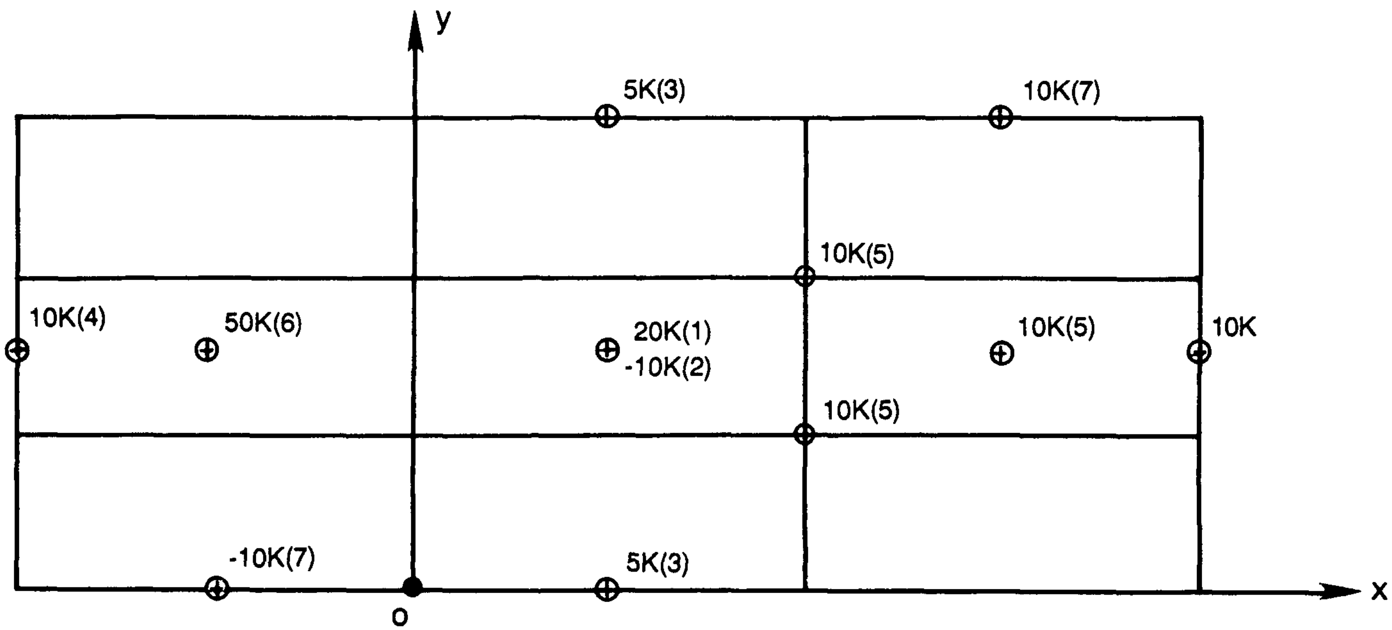
```
****   End of data in input file   ***
     Hit <return> to continue, enter data from keyboard,
     Data entry will be saved in a user specified file.

Enter number of cargo weights     :1
  1
For each weight load enter the following:
----------------------------------------
Weight, and global coordinates    :10000. 0. 00. 0.
 10000.0    0.0    0.0    0.0
--------------------------------------------------------------------------------
  <<<<< LOAD STEP  9 >>>>>


      WETCAN: Equilibrium shape of the barge.
      Approximate draft  =    3.45 feet,
      heel angle (roll)    =   -1.75 degrees,
      trim angle (pitch)   =   -0.65 degrees.

Enter: 1=add loads, 2=new load plan, 3=modify barge, 4=exit:  4
4
**** STOP
```

Figure A-1.(Continued)



(Numbers in parenthesis indicate the sequence of loading procedure.)

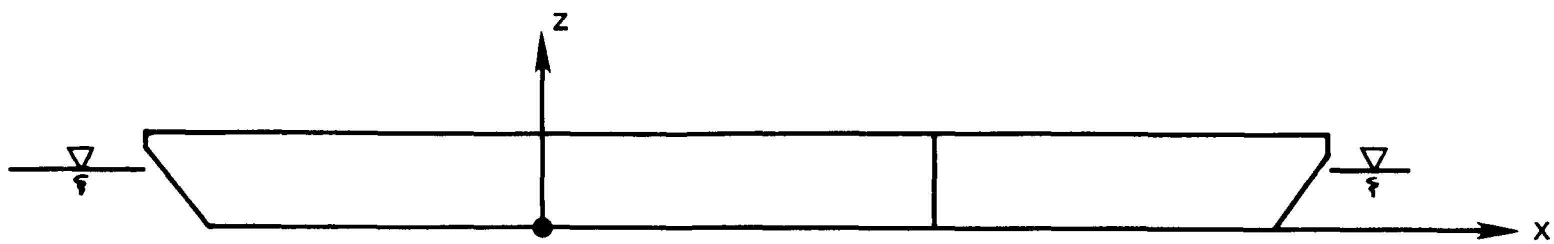


Figure A-2.
A sketch of the 3 by 3 ISO barge used for the sample problem.

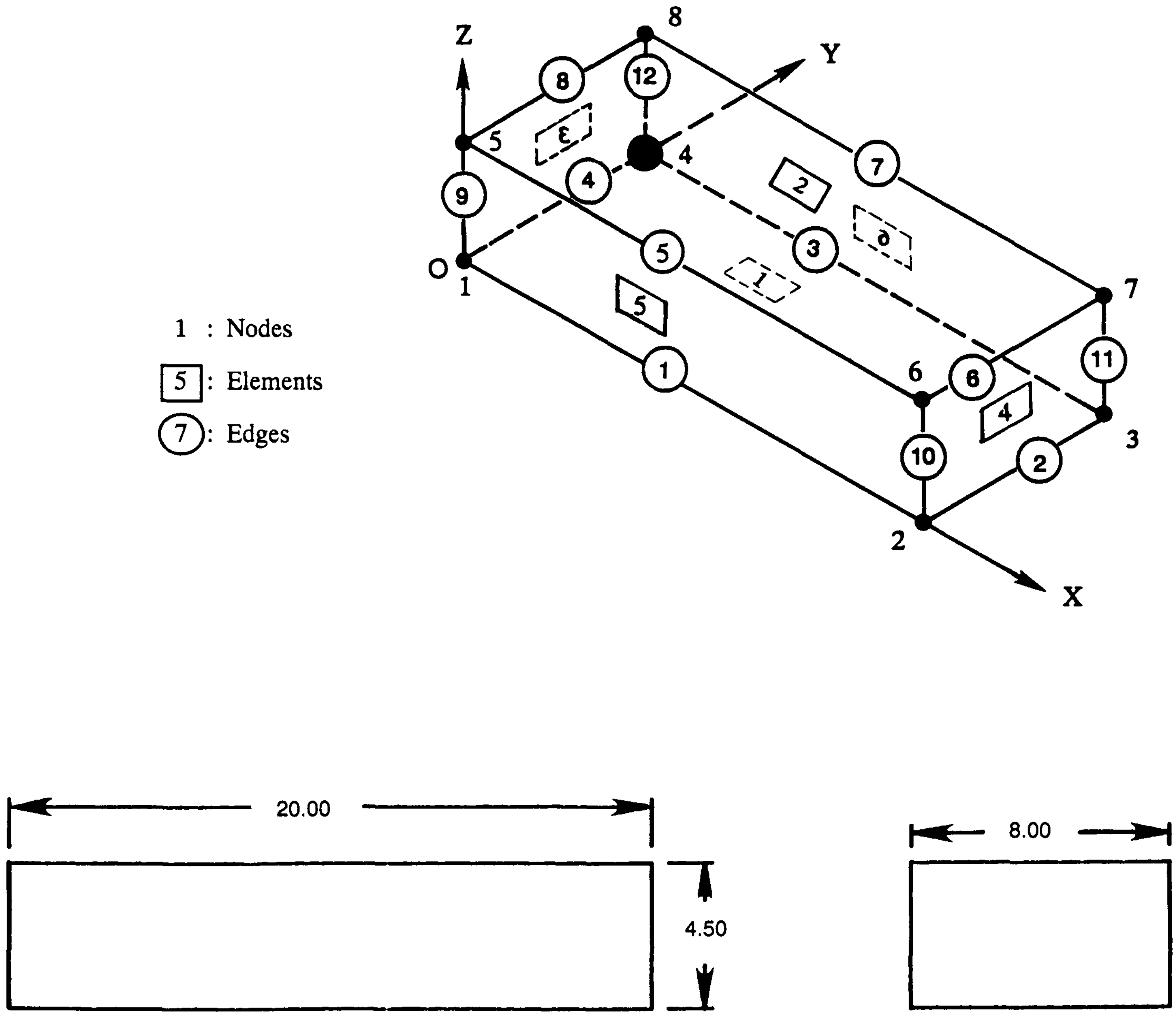


Figure A-3.
Sketch of the ISO-20 pontoon.

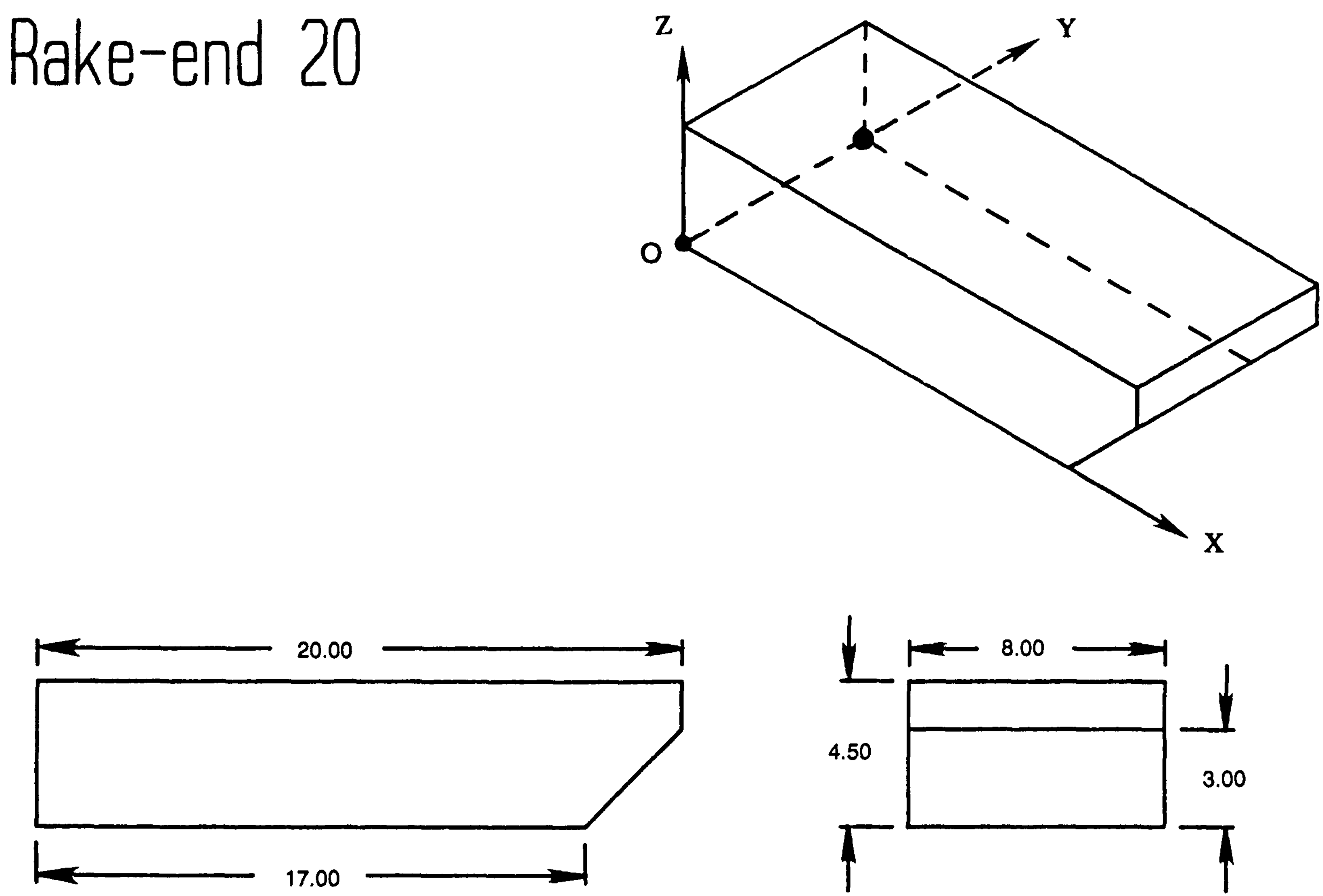


Figure A-4.
Sketch of the rake-end-20 pontoon.

```
***************************************************************
*                         WELCOME TO                          *
*                                                             *
*                         I S A P !                           *
*                                                             *
*                                                             *
*            an Intact Stability Analysis Program             *
*            for the floating pontoon structures.             *
*                                                             *
*                Version 1.1, 23 February, 1990               *
*                                                             *
*                   Erick T. Huang, PhD                       *
*              Naval Civil Engineering Laboratory             *
*                  Port Hueneme, CA  93043                    *
*           Tel. (805) 982-1256, or  A/V  551-1256.           *
***************************************************************


1
 **** New job ****

 **** Input filename: INPUT


DRYCAN:  Summary of Can #  1: ISO 20


DRYCAN: Total weight =   12984.4
   Center of gravity =     10.00      4.00      2.25
           Deck area =    160.00


DRYCAN:  Summary of Can #  2: RAKE END 20


DRYCAN: Total weight =   12351.2
   Center of gravity =      9.57      4.00      2.36
           Deck area =    146.00


    ===============
    = FABRICATION =
    ===============


    FABRIC: Can #  1 has  6 faces, and  12 edges... Nodal points =  8

    FABRIC: Can #  2 has  6 faces, and  12 edges... Nodal points =  8

    FABRIC: Can #  3 has  6 faces, and  12 edges... Nodal points =  8

    FABRIC: Can #  4 has  7 faces, and  15 edges... Nodal points = 10
```

Figure A-5.
Sample output file for the 3 by 3 pontoon barge analysis.

FABRIC: Can # 5 has 7 faces, and 15 edges... Nodal points = 10

FABRIC: Can # 6 has 7 faces, and 15 edges... Nodal points = 10

FABRIC: Can # 7 has 7 faces, and 15 edges... Nodal points = 10

FABRIC: Can # 8 has 7 faces, and 15 edges... Nodal points = 10

FABRIC: Can # 9 has 7 faces, and 15 edges... Nodal points = 10

***** Summary of the Barge *****

Total weight = 113060. pounds,
Center of gravity: 10.00 12.00 2.32
Total deck area = 1356.00 square feet.

FABRIC: Total number of nodal points of barge = 84

*** Node Coordinates:

0.00	0.00	0.00	20.00	0.00	0.00	20.00	8.00	0.00
0.00	8.00	0.00	0.00	0.00	4.50	20.00	0.00	4.50
20.00	8.00	4.50	0.00	8.00	4.50	0.00	8.00	0.00
20.00	8.00	0.00	20.00	16.00	0.00	0.00	16.00	0.00
0.00	8.00	4.50	20.00	8.00	4.50	20.00	16.00	4.50
0.00	16.00	4.50	0.00	16.00	0.00	20.00	16.00	0.00
20.00	24.00	0.00	0.00	24.00	0.00	0.00	16.00	4.50
20.00	16.00	4.50	20.00	24.00	4.50	0.00	24.00	4.50
20.00	0.00	0.00	37.00	0.00	0.00	37.00	8.00	0.00
20.00	8.00	0.00	20.00	0.00	4.50	40.00	0.00	4.50
40.00	8.00	4.50	20.00	8.00	4.50	40.00	0.00	3.00
40.00	8.00	3.00	20.00	8.00	0.00	37.00	8.00	0.00
37.00	16.00	0.00	20.00	16.00	0.00	20.00	8.00	4.50
40.00	8.00	4.50	40.00	16.00	4.50	20.00	16.00	4.50
40.00	8.00	3.00	40.00	16.00	3.00	20.00	16.00	0.00
37.00	16.00	0.00	37.00	24.00	0.00	20.00	24.00	0.00
20.00	16.00	4.50	40.00	16.00	4.50	40.00	24.00	4.50
20.00	24.00	4.50	40.00	16.00	3.00	40.00	24.00	3.00
0.00	8.00	0.00	-17.00	8.00	0.00	-17.00	0.00	0.00
0.00	0.00	0.00	0.00	8.00	4.50	-20.00	8.00	4.50
-20.00	0.00	4.50	0.00	0.00	4.50	-20.00	8.00	3.00
-20.00	0.00	3.00	0.00	16.00	0.00	-17.00	16.00	0.00
-17.00	8.00	0.00	0.00	8.00	0.00	0.00	16.00	4.50
-20.00	16.00	4.50	-20.00	8.00	4.50	0.00	8.00	4.50
-20.00	16.00	3.00	-20.00	8.00	3.00	0.00	24.00	0.00
-17.00	24.00	0.00	-17.00	16.00	0.00	0.00	16.00	0.00
0.00	24.00	4.50	-20.00	24.00	4.50	-20.00	16.00	4.50
0.00	16.00	4.50	-20.00	24.00	3.00	-20.00	16.00	3.00

<<<<< LAUNCH >>>>>

WETCAN: Equilibrium shape of the barge.
Approximate draft = 1.33 feet,
heel angle (roll) = 0.00 degrees,
trim angle (pitch) = 0.00 degrees.

Figure A-5. (Continued)

```
-10.00  -12.00   -1.33;   10.00  -12.00   -1.33;   10.00   -4.00   -1.33;
-10.00   -4.00   -1.33;  -10.00  -12.00    3.17;   10.00  -12.00    3.17;
 10.00   -4.00    3.17;  -10.00   -4.00    3.17;  -10.00   -4.00   -1.33;
 10.00   -4.00   -1.33;   10.00    4.00   -1.33;  -10.00    4.00   -1.33;
-10.00   -4.00    3.17;   10.00   -4.00    3.17;   10.00    4.00    3.17;
-10.00    4.00    3.17;  -10.00    4.00   -1.33;   10.00    4.00   -1.33;
 10.00   12.00   -1.33;  -10.00   12.00   -1.33;  -10.00    4.00    3.17;
 10.00    4.00    3.17;   10.00   12.00    3.17;  -10.00   12.00    3.17;
 10.00  -12.00   -1.33;   27.00  -12.00   -1.33;   27.00   -4.00   -1.33;
 10.00   -4.00   -1.33;   10.00  -12.00    3.17;   30.00  -12.00    3.17;
 30.00   -4.00    3.17;   10.00   -4.00    3.17;   30.00  -12.00    1.67;
 30.00   -4.00    1.67;   10.00   -4.00   -1.33;   27.00   -4.00   -1.33;
 27.00    4.00   -1.33;   10.00    4.00   -1.33;   10.00   -4.00    3.17;
 30.00   -4.00    3.17;   30.00    4.00    3.17;   10.00    4.00    3.17;
 30.00   -4.00    1.67;   30.00    4.00    1.67;   10.00    4.00   -1.33;
 27.00    4.00   -1.33;   27.00   12.00   -1.33;   10.00   12.00   -1.33;
 10.00    4.00    3.17;   30.00    4.00    3.17;   30.00   12.00    3.17;
 10.00   12.00    3.17;   30.00    4.00    1.67;   30.00   12.00    1.67;
-10.00   -4.00   -1.33;  -27.00   -4.00   -1.33;  -27.00  -12.00   -1.33;
-10.00  -12.00   -1.33;  -10.00   -4.00    3.17;  -30.00   -4.00    3.17;
-30.00  -12.00    3.17;  -10.00  -12.00    3.17;  -30.00   -4.00    1.67;
-30.00  -12.00    1.67;  -10.00    4.00   -1.33;  -27.00    4.00   -1.33;
-27.00   -4.00   -1.33;  -10.00   -4.00   -1.33;  -10.00    4.00    3.17;
-30.00    4.00    3.17;  -30.00   -4.00    3.17;  -10.00   -4.00    3.17;
-30.00    4.00    1.67;  -30.00   -4.00    1.67;  -10.00   12.00   -1.33;
-27.00   12.00   -1.33;  -27.00    4.00   -1.33;  -10.00    4.00   -1.33;
-10.00   12.00    3.17;  -30.00   12.00    3.17;  -30.00    4.00    3.17;
-10.00    4.00    3.17;  -30.00   12.00    1.67;  -30.00    4.00    1.67;


LOAD: add  1 new loads in this load step.

Load #   1 (in fabricate coor.): 20000.0    10.0    12.0     4.5

LOAD: Barge orientation before new loads      0.00     0.00     0.00

 *** Current postions of the loads. ***

LOAD: (water coord.) #  1            20000.0       0.000      0.000      3.170

LOAD: Barge weight including loads     133060.     0.000      0.000      1.316
     Unbalanced forces due to new loads:     20000.         0.         0.


 <<<<< LOAD STEP   1 >>>>>


    WETCAN: Equilibrium shape of the barge.
    Approximate draft  =      1.56 feet,
    heel angle (roll)     =     0.00 degrees,
    trim angle (pitch)    =     0.00 degrees.

-10.00  -12.00   -1.56;   10.00  -12.00   -1.56;   10.00   -4.00   -1.56;
-10.00   -4.00   -1.56;  -10.00  -12.00    2.94;   10.00  -12.00    2.94;
 10.00   -4.00    2.94;  -10.00   -4.00    2.94;  -10.00   -4.00   -1.56;
 10.00   -4.00   -1.56;   10.00    4.00   -1.56;  -10.00    4.00   -1.56;
-10.00   -4.00    2.94;   10.00   -4.00    2.94;   10.00    4.00    2.94;
-10.00    4.00    2.94;  -10.00    4.00   -1.56;   10.00    4.00   -1.56;
 10.00   12.00   -1.56;  -10.00   12.00   -1.56;  -10.00    4.00    2.94;
```

Figure A-5, (Continued)

```
  10.00    4.00    2.94;   10.00   12.00    2.94;  -10.00   12.00    2.94;
  10.00  -12.00   -1.56;   27.00  -12.00   -1.56;   27.00   -4.00   -1.56;
  10.00   -4.00   -1.56;   10.00  -12.00    2.94;   30.00  -12.00    2.94;
  30.00   -4.00    2.94;   10.00   -4.00    2.94;   30.00  -12.00    1.44;
  30.00   -4.00    1.44;   10.00   -4.00   -1.56;   27.00   -4.00   -1.56;
  27.00    4.00   -1.56;   10.00    4.00   -1.56;   10.00   -4.00    2.94;
  30.00   -4.00    2.94;   30.00    4.00    2.94;   10.00    4.00    2.94;
  30.00   -4.00    1.44;   30.00    4.00    1.44;   10.00    4.00   -1.56;
  27.00    4.00   -1.56;   27.00   12.00   -1.56;   10.00   12.00   -1.56;
  10.00    4.00    2.94;   30.00    4.00    2.94;   30.00   12.00    2.94;
  10.00   12.00    2.94;   30.00    4.00    1.44;   30.00   12.00    1.44;
 -10.00   -4.00   -1.56;  -27.00   -4.00   -1.56;  -27.00  -12.00   -1.56;
 -10.00  -12.00   -1.56;  -10.00   -4.00    2.94;  -30.00   -4.00    2.94;
 -30.00  -12.00    2.94;  -10.00  -12.00    2.94;  -30.00   -4.00    1.44;
 -30.00  -12.00    1.44;  -10.00    4.00   -1.56;  -27.00    4.00   -1.56;
 -27.00   -4.00   -1.56;  -10.00   -4.00   -1.56;  -10.00    4.00    2.94;
 -30.00    4.00    2.94;  -30.00   -4.00    2.94;  -10.00   -4.00    2.94;
 -30.00    4.00    1.44;  -30.00   -4.00    1.44;  -10.00   12.00   -1.56;
 -27.00   12.00   -1.56;  -27.00    4.00   -1.56;  -10.00    4.00   -1.56;
 -10.00   12.00    2.94;  -30.00   12.00    2.94;  -30.00    4.00    2.94;
 -10.00    4.00    2.94;  -30.00   12.00    1.44;  -30.00    4.00    1.44;


LOAD: add  1 new loads in this load step.

Load #   2 (in fabricate coor.):-10000.0   10.0   12.0    4.5

LOAD: Barge orientation before new loads      0.00     0.00     0.00

 *** Current postions of the loads. ***

LOAD: (water coord.) #  1           20000.0       0.000     0.000      2.941
LOAD: (water coord.) #  2          -10000.0       0.000     0.000      2.941

LOAD: Barge weight including loads    123060.     0.000     0.000      0.937
      Unbalanced forces due to new loads:   -10000.         0.         0.


 <<<<< LOAD STEP  2 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft  =     1.44 feet,
     heel angle (roll)     =    0.00 degrees,
     trim angle (pitch)    =    0.00 degrees.

 -10.00  -12.00   -1.44;   10.00  -12.00   -1.44;   10.00   -4.00   -1.44;
 -10.00   -4.00   -1.44;  -10.00  -12.00    3.06;   10.00  -12.00    3.06;
  10.00   -4.00    3.06;  -10.00   -4.00    3.06;  -10.00   -4.00   -1.44;
  10.00   -4.00   -1.44;   10.00    4.00   -1.44;  -10.00    4.00   -1.44;
 -10.00   -4.00    3.06;   10.00   -4.00    3.06;   10.00    4.00    3.06;
 -10.00    4.00    3.06;  -10.00    4.00   -1.44;   10.00    4.00   -1.44;
  10.00   12.00   -1.44;  -10.00   12.00   -1.44;  -10.00    4.00    3.06;
  10.00    4.00    3.06;   10.00   12.00    3.06;  -10.00   12.00    3.06;
  10.00  -12.00   -1.44;   27.00  -12.00   -1.44;   27.00   -4.00   -1.44;
  10.00   -4.00   -1.44;   10.00  -12.00    3.06;   30.00  -12.00    3.06;
  30.00   -4.00    3.06;   10.00   -4.00    3.06;   30.00  -12.00    1.56;
  30.00   -4.00    1.56;   10.00   -4.00   -1.44;   27.00   -4.00   -1.44;
  27.00    4.00   -1.44;   10.00    4.00   -1.44;   10.00   -4.00    3.06;
  30.00   -4.00    3.06;   30.00    4.00    3.06;   10.00    4.00    3.06;
```

Figure A-5. (Continued)

30.00	-4.00	1.56;	30.00	4.00	1.56;	10.00	4.00	-1.44;
27.00	4.00	-1.44;	27.00	12.00	-1.44;	10.00	12.00	-1.44;
10.00	4.00	3.06;	30.00	4.00	3.06;	30.00	12.00	3.06;
10.00	12.00	3.06;	30.00	4.00	1.56;	30.00	12.00	1.56;
-10.00	-4.00	-1.44;	-27.00	-4.00	-1.44;	-27.00	-12.00	-1.44;
-10.00	-12.00	-1.44;	-10.00	-4.00	3.06;	-30.00	-4.00	3.06;
-30.00	-12.00	3.06;	-10.00	-12.00	3.06;	-30.00	-4.00	1.56;
-30.00	-12.00	1.56;	-10.00	4.00	-1.44;	-27.00	4.00	-1.44;
-27.00	-4.00	-1.44;	-10.00	-4.00	-1.44;	-10.00	4.00	3.06;
-30.00	4.00	3.06;	-30.00	-4.00	3.06;	-10.00	-4.00	3.06;
-30.00	4.00	1.56;	-30.00	-4.00	1.56;	-10.00	12.00	-1.44;
-27.00	12.00	-1.44;	-27.00	4.00	-1.44;	-10.00	4.00	-1.44;
-10.00	12.00	3.06;	-30.00	12.00	3.06;	-30.00	4.00	3.06;
-10.00	4.00	3.06;	-30.00	12.00	1.56;	-30.00	4.00	1.56;

LOAD: add 2 new loads in this load step.

Load # 3 (in fabricate coor.): 5000.0 10.0 0.0 4.5
Load # 4 (in fabricate coor.): 5000.0 10.0 24.0 4.5

LOAD: Barge orientation before new loads 0.00 0.00 0.00

*** Current postions of the loads. ***

LOAD: (water coord.) # 1	20000.0	0.000	0.000	3.055
LOAD: (water coord.) # 2	-10000.0	0.000	0.000	3.055
LOAD: (water coord.) # 3	5000.0	0.000	-12.000	3.055
LOAD: (water coord.) # 4	5000.0	0.000	12.000	3.055

LOAD: Barge weight including loads 133060. 0.000 0.000 1.202
Unbalanced forces due to new loads: 10000. 0. 0.

<<<<< LOAD STEP 3 >>>>>

WETCAN: Equilibrium shape of the barge.
Approximate draft = 1.56 feet,
heel angle (roll) = 0.00 degrees,
trim angle (pitch) = 0.00 degrees.

-10.00	-12.00	-1.56;	10.00	-12.00	-1.56;	10.00	-4.00	-1.56;
-10.00	-4.00	-1.56;	-10.00	-12.00	2.94;	10.00	-12.00	2.94;
10.00	-4.00	2.94;	-10.00	-4.00	2.94;	-10.00	-4.00	-1.56;
10.00	-4.00	-1.56;	10.00	4.00	-1.56;	-10.00	4.00	-1.56;
-10.00	-4.00	2.94;	10.00	-4.00	2.94;	10.00	4.00	2.94;
-10.00	4.00	2.94;	-10.00	4.00	-1.56;	10.00	4.00	-1.56;
10.00	12.00	-1.56;	-10.00	12.00	-1.56;	-10.00	4.00	2.94;
10.00	4.00	2.94;	10.00	12.00	2.94;	-10.00	12.00	2.94;
10.00	-12.00	-1.56;	27.00	-12.00	-1.56;	27.00	-4.00	-1.56;
10.00	-4.00	-1.56;	10.00	-12.00	2.94;	30.00	-12.00	2.94;
30.00	-4.00	2.94;	10.00	-4.00	2.94;	30.00	-12.00	1.44;
30.00	-4.00	1.44;	10.00	-4.00	-1.56;	27.00	-4.00	-1.56;
27.00	4.00	-1.56;	10.00	4.00	-1.56;	10.00	-4.00	2.94;
30.00	-4.00	2.94;	30.00	4.00	2.94;	10.00	4.00	2.94;
30.00	-4.00	1.44;	30.00	4.00	1.44;	10.00	4.00	-1.56;
27.00	4.00	-1.56;	27.00	12.00	-1.56;	10.00	12.00	-1.56;
10.00	4.00	2.94;	30.00	4.00	2.94;	30.00	12.00	2.94;
10.00	12.00	2.94;	30.00	4.00	1.44;	30.00	12.00	1.44;

Figure A-5, (Continued)

```
-10.00   -4.00   -1.56;  -27.00   -4.00   -1.56;  -27.00  -12.00   -1.56;
-10.00  -12.00   -1.56;  -10.00   -4.00    2.94;  -30.00   -4.00    2.94;
-30.00  -12.00    2.94;  -10.00  -12.00    2.94;  -30.00   -4.00    1.44;
-30.00  -12.00    1.44;  -10.00    4.00   -1.56;  -27.00    4.00   -1.56;
-27.00   -4.00   -1.56;  -10.00   -4.00   -1.56;  -10.00    4.00    2.94;
-30.00    4.00    2.94;  -30.00   -4.00    2.94;  -10.00   -4.00    2.94;
-30.00    4.00    1.44;  -30.00   -4.00    1.44;  -10.00   12.00   -1.56;
-27.00   12.00   -1.56;  -27.00    4.00   -1.56;  -10.00    4.00   -1.56;
-10.00   12.00    2.94;  -30.00   12.00    2.94;  -30.00    4.00    2.94;
-10.00    4.00    2.94;  -30.00   12.00    1.44;  -30.00    4.00    1.44;


LOAD: add  1 new loads in this load step.

Load #   5 (in fabricate coor.): 10000.0  -20.0   12.0    4.5

LOAD: Barge orientation before new loads      0.00     0.00     0.00

 *** Current postions of the loads. ***

LOAD: (water coord.) #  1           20000.0       0.000     0.000      2.941
LOAD: (water coord.) #  2          -10000.0       0.000     0.000      2.941
LOAD: (water coord.) #  3            5000.0       0.000   -12.000      2.941
LOAD: (water coord.) #  4            5000.0       0.000    12.000      2.941
LOAD: (water coord.) #  5           10000.0     -30.000     0.000      2.941

LOAD: Barge weight including loads     143060.    -2.097     0.000      1.217
      Unbalanced forces due to new loads:     10000.          0.  -300000.


 <<<<< LOAD STEP  4 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft  =    2.01 feet,
     heel angle (roll)    =    0.00 degrees,
     trim angle (pitch)   =   -0.72 degrees.

 -9.62  -12.00   -1.80;   10.38  -12.00   -1.54;   10.38   -4.00   -1.54;
 -9.62   -4.00   -1.80;   -9.67  -12.00    2.70;   10.32  -12.00    2.95;
 10.32   -4.00    2.95;   -9.67   -4.00    2.70;   -9.62   -4.00   -1.80;
 10.38   -4.00   -1.54;   10.38    4.00   -1.54;   -9.62    4.00   -1.80;
 -9.67   -4.00    2.70;   10.32   -4.00    2.95;   10.32    4.00    2.95;
 -9.67    4.00    2.70;   -9.62    4.00   -1.80;   10.38    4.00   -1.54;
 10.38   12.00   -1.54;   -9.62   12.00   -1.80;   -9.67    4.00    2.70;
 10.32    4.00    2.95;   10.32   12.00    2.95;   -9.67   12.00    2.70;
 10.38  -12.00   -1.54;   27.38  -12.00   -1.33;   27.38   -4.00   -1.33;
 10.38   -4.00   -1.54;   10.32  -12.00    2.95;   30.32  -12.00    3.21;
 30.32   -4.00    3.21;   10.32   -4.00    2.95;   30.34  -12.00    1.71;
 30.34   -4.00    1.71;   10.38   -4.00   -1.54;   27.38   -4.00   -1.33;
 27.38    4.00   -1.33;   10.38    4.00   -1.54;   10.32   -4.00    2.95;
 30.32   -4.00    3.21;   30.32    4.00    3.21;   10.32    4.00    2.95;
 30.34   -4.00    1.71;   30.34    4.00    1.71;   10.38    4.00   -1.54;
 27.38    4.00   -1.33;   27.38   12.00   -1.33;   10.38   12.00   -1.54;
 10.32    4.00    2.95;   30.32    4.00    3.21;   30.32   12.00    3.21;
 10.32   12.00    2.95;   30.34    4.00    1.71;   30.34   12.00    1.71;
 -9.62   -4.00   -1.80;  -26.62   -4.00   -2.01;  -26.62  -12.00   -2.01;
 -9.62  -12.00   -1.80;   -9.67   -4.00    2.70;  -29.67   -4.00    2.45;
-29.67  -12.00    2.45;   -9.67  -12.00    2.70;  -29.65   -4.00    0.95;
-29.65  -12.00    0.95;   -9.62    4.00   -1.80;  -26.62    4.00   -2.01;
```

Figure A-5. (Continued)

```
-26.62   -4.00   -2.01;   -9.62   -4.00   -1.80;   -9.67    4.00    2.70;
-29.67    4.00    2.45;  -29.67   -4.00    2.45;   -9.67   -4.00    2.70;
-29.65    4.00    0.95;  -29.65   -4.00    0.95;   -9.62   12.00   -1.80;
-26.62   12.00   -2.01;  -26.62    4.00   -2.01;   -9.62    4.00   -1.80;
 -9.67   12.00    2.70;  -29.67   12.00    2.45;  -29.67    4.00    2.45;
 -9.67    4.00    2.70;  -29.65   12.00    0.95;  -29.65    4.00    0.95;


LOAD: add  1 new loads in this load step.

Load #   6 (in fabricate coor.): 10000.0   40.0   12.0   4.5

LOAD: Barge orientation before new loads     0.00   -0.72    0.00

 *** Current postions of the loads. ***

LOAD: (water coord.) #  1           20000.0       0.325     0.000     2.829
LOAD: (water coord.) #  2          -10000.0       0.325     0.000     2.829
LOAD: (water coord.) #  3            5000.0       0.325   -12.000     2.829
LOAD: (water coord.) #  4            5000.0       0.325    12.000     2.829
LOAD: (water coord.) #  5           10000.0     -29.673     0.000     2.452
LOAD: (water coord.) #  6           10000.0      30.322     0.000     3.206

LOAD: Barge weight including loads    153060.     0.345     0.000     1.218
      Unbalanced forces due to new loads:    10000.        0.   303224.


 <<<<< LOAD STEP  5 >>>>>


    WETCAN: Equilibrium shape of the barge.
    Approximate draft  =     1.79 feet,
    heel angle (roll)    =    0.00 degrees,
    trim angle (pitch)   =    0.00 degrees.

-10.00  -12.00   -1.79;   10.00  -12.00   -1.79;   10.00   -4.00   -1.79;
-10.00   -4.00   -1.79;  -10.00  -12.00    2.71;   10.00  -12.00    2.71;
 10.00   -4.00    2.71;  -10.00   -4.00    2.71;  -10.00   -4.00   -1.79;
 10.00   -4.00   -1.79;   10.00    4.00   -1.79;  -10.00    4.00   -1.79;
-10.00   -4.00    2.71;   10.00   -4.00    2.71;   10.00    4.00    2.71;
-10.00    4.00    2.71;  -10.00    4.00   -1.79;   10.00    4.00   -1.79;
 10.00   12.00   -1.79;  -10.00   12.00   -1.79;  -10.00    4.00    2.71;
 10.00    4.00    2.71;   10.00   12.00    2.71;  -10.00   12.00    2.71;
 10.00  -12.00   -1.79;   27.00  -12.00   -1.79;   27.00   -4.00   -1.79;
 10.00   -4.00   -1.79;   10.00  -12.00    2.71;   30.00  -12.00    2.71;
 30.00   -4.00    2.71;   10.00   -4.00    2.71;   30.00  -12.00    1.21;
 30.00   -4.00    1.21;   10.00   -4.00   -1.79;   27.00   -4.00   -1.79;
 27.00    4.00   -1.79;   10.00    4.00   -1.79;   10.00   -4.00    2.71;
 30.00   -4.00    2.71;   30.00    4.00    2.71;   10.00    4.00    2.71;
 30.00   -4.00    1.21;   30.00    4.00    1.21;   10.00    4.00   -1.79;
 27.00    4.00   -1.79;   27.00   12.00   -1.79;   10.00   12.00   -1.79;
 10.00    4.00    2.71;   30.00    4.00    2.71;   30.00   12.00    2.71;
 10.00   12.00    2.71;   30.00    4.00    1.21;   30.00   12.00    1.21;
-10.00   -4.00   -1.79;  -27.00   -4.00   -1.79;  -27.00  -12.00   -1.79;
-10.00  -12.00   -1.79;  -10.00   -4.00    2.71;  -30.00   -4.00    2.71;
-30.00  -12.00    2.71;  -10.00  -12.00    2.71;  -30.00   -4.00    1.21;
-30.00  -12.00    1.21;  -10.00    4.00   -1.79;  -27.00    4.00   -1.79;
-27.00   -4.00   -1.79;  -10.00   -4.00   -1.79;  -10.00    4.00    2.71;
-30.00    4.00    2.71;  -30.00   -4.00    2.71;  -10.00   -4.00    2.71;
-30.00    4.00    1.21;  -30.00   -4.00    1.21;  -10.00   12.00   -1.79;
```

Figure A-5.(Continued)

```
 -27.00   12.00   -1.79;  -27.00    4.00   -1.79;  -10.00    4.00   -1.79;
 -10.00   12.00    2.71;  -30.00   12.00    2.71;  -30.00    4.00    2.71;
 -10.00    4.00    2.71;  -30.00   12.00    1.21;  -30.00    4.00    1.21;


LOAD: add  3 new loads in this load step.

Load #   7 (in fabricate coor.): 10000.0   20.0    8.0    4.5
Load #   8 (in fabricate coor.): 10000.0   20.0   16.0    4.5
Load #   9 (in fabricate coor.): 10000.0   30.0   12.0    4.5

LOAD: Barge orientation before new loads     0.00    0.00    0.00

 *** Current postions of the loads. ***

LOAD: (water coord.) #  1          20000.0       0.000     0.000     2.714
LOAD: (water coord.) #  2         -10000.0       0.000     0.000     2.714
LOAD: (water coord.) #  3           5000.0       0.000   -12.000     2.714
LOAD: (water coord.) #  4           5000.0       0.000    12.000     2.714
LOAD: (water coord.) #  5          10000.0     -30.000     0.000     2.714
LOAD: (water coord.) #  6          10000.0      30.000     0.000     2.714
LOAD: (water coord.) #  7          10000.0      10.000    -4.000     2.714
LOAD: (water coord.) #  8          10000.0      10.000     4.000     2.714
LOAD: (water coord.) #  9          10000.0      20.000     0.000     2.714

LOAD: Barge weight including loads     183060.     2.185     0.000     1.367
      Unbalanced forces due to new loads:     30000.        0.   400005.


 <<<<< LOAD STEP  6 >>>>>


    WETCAN: Equilibrium shape of the barge.
    Approximate draft  =     2.55 feet,
    heel angle (roll)    =     0.00 degrees,
    trim angle (pitch)   =     0.92 degrees.

-10.50  -12.00   -1.96;    9.50  -12.00   -2.28;    9.50   -4.00   -2.28;
-10.50   -4.00   -1.96;  -10.43  -12.00    2.54;    9.57  -12.00    2.22;
  9.57   -4.00    2.22;  -10.43   -4.00    2.54;  -10.50   -4.00   -1.96;
  9.50   -4.00   -2.28;    9.50    4.00   -2.28;  -10.50    4.00   -1.96;
-10.43   -4.00    2.54;    9.57   -4.00    2.22;    9.57    4.00    2.22;
-10.43    4.00    2.54;  -10.50    4.00   -1.96;    9.50    4.00   -2.28;
  9.50   12.00   -2.28;  -10.50   12.00   -1.96;  -10.43    4.00    2.54;
  9.57    4.00    2.22;    9.57   12.00    2.22;  -10.43   12.00    2.54;
  9.50  -12.00   -2.28;   26.50  -12.00   -2.55;   26.50   -4.00   -2.55;
  9.50   -4.00   -2.[illegible]    9.57  -12.00    2.22;   29.57  -12.00    1.90;
 29.57   -4.00   1[illegible]    9.57   -4.00    2.22;   29.54  -12.00    0.40;
 29.54   -4.00   0.[illegible];    9.[illegible]0   -4.00   -2.28;   26.50   -4.00   -2.55;
 26.50    4.00   -2.55;    9.50    4.00   -2.28;    9.57   -4.00    2.22;
 29.57   -4.00    1.90;   29.57    4.00    1.90;    9.57    4.00    2.22;
 29.54   -4.00    0.40;   29.54    4.00    0.40;    9.50    4.00   -2.28;
 26.50    4.00   -2.55;   26.50   12.00   -2.55;    9.50   12.00   -2.28;
  9.57    4.00    2.22;   29.57    4.00    1.90;   29.57   12.00    1.90;
  9.57   12.00    2.22;   29.54    4.00    0.40;   29.54   12.00    0.40;
-10.50   -4.00   -1.96;  -27.50   -4.00   -1.69;  -27.50  -12.00   -1.69;
-10.50  -12.00   -1.[illegible]6;  -10.43   -4.00    2.54;  -30.43   -4.00    2.86;
-30.43  -12.00    2.86;  -10.43  -12.00    2.54;  -30.45   -4.00    1.36;
-30.45  -12.00    1.36;  -10.50    4.00   -1.96;  -27.50    4.00   -1.69;
-27.50   -4.00   -1.69;  -10.50   -4.00   -1.96;  -10.43    4.00    2.54;
```

Figure A-5.(Continued)

-30.43	4.00	2.86;	-30.43	-4.00	2.86;	-10.43	-4.00	2.54;
-30.45	4.00	1.36;	-30.45	-4.00	1.36;	-10.50	12.00	-1.96;
-27.50	12.00	-1.69;	-27.50	4.00	-1.69;	-10.50	4.00	-1.96;
-10.43	12.00	2.54;	-30.43	12.00	2.86;	-30.43	4.00	2.86;
-10.43	4.00	2.54;	-30.45	12.00	1.36;	-30.45	4.00	1.36;

LOAD: add 1 new loads in this load step.

Load # 10 (in fabricate coor.): 50000.0 -10.0 12.0 4.5

LOAD: Barge orientation before new loads 0.00 0.92 0.00

*** Current postions of the loads. ***

LOAD: (water coord.) # 1	20000.0	-0.429	0.000	2.380
LOAD: (water coord.) # 2	-10000.0	-0.429	0.000	2.380
LOAD: (water coord.) # 3	5000.0	-0.429	-12.000	2.380
LOAD: (water coord.) # 4	5000.0	-0.429	12.000	2.380
LOAD: (water coord.) # 5	10000.0	-30.425	0.000	2.861
LOAD: (water coord.) # 6	10000.0	29.567	0.000	1.898
LOAD: (water coord.) # 7	10000.0	9.570	-4.000	2.219
LOAD: (water coord.) # 8	10000.0	9.570	4.000	2.219
LOAD: (water coord.) # 9	10000.0	19.568	0.000	2.059
LOAD: (water coord.) # 10	50000.0	-20.426	0.000	2.701

LOAD: Barge weight including loads 233060. -3.020 0.000 1.363
Unbalanced forces due to new loads: 50000. -1. -1021320.

<<<<< LOAD STEP 7 >>>>>

WETCAN: Equilibrium shape of the barge.
Approximate draft = 3.29 feet,
heel angle (roll) = 0.00 degrees,
trim angle (pitch) = -1.31 degrees.

-9.44	-12.00	-2.90;	10.56	-12.00	-2.44;	10.56	-4.00	-2.44;
-9.44	-4.00	-2.90;	-9.54	-12.00	1.60;	10.45	-12.00	2.06;
10.45	-4.00	2.06;	-9.54	-4.00	1.60;	-9.44	-4.00	-2.90;
10.56	-4.00	-2.44;	10.56	4.00	-2.44;	-9.44	4.00	-2.90;
-9.54	-4.00	1.60;	10.45	-4.00	2.06;	10.45	4.00	2.06;
-9.54	4.00	1.60;	-9.44	4.00	-2.90;	10.56	4.00	-2.44;
10.56	12.00	-2.44;	-9.44	12.00	-2.90;	-9.54	4.00	1.60;
10.45	4.00	2.06;	10.45	12.00	2.06;	-9.54	12.00	1.60;
10.56	-12.00	-2.44;	27.55	-12.00	-2.05;	27.55	-4.00	-2.05;
10.56	-4.00	-2.44;	10.45	-12.00	2.06;	30.45	-12.00	2.52;
30.45	-4.00	2.52;	10.45	-4.00	2.06;	30.48	-12.00	1.02;
30.48	-4.00	1.02;	10.56	-4.00	-2.44;	27.55	-4.00	-2.05;
27.55	4.00	-2.05;	10.56	4.00	-2.44;	10.45	-4.00	2.06;
30.45	-4.00	2.52;	30.45	4.00	2.52;	10.45	4.00	2.06;
30.48	-4.00	1.02;	30.48	4.00	1.02;	10.56	4.00	-2.44;
27.55	4.00	-2.05;	27.55	12.00	-2.05;	10.56	12.00	-2.44;
10.45	4.00	2.06;	30.45	4.00	2.52;	30.45	12.00	2.52;
10.45	12.00	2.06;	30.48	4.00	1.02;	30.48	12.00	1.02;
-9.44	-4.00	-2.90;	-26.43	-4.00	-3.29;	-26.43	-12.00	-3.29;
-9.44	-12.00	-2.90;	-9.54	-4.00	1.60;	-29.54	-4.00	1.14;
-29.54	-12.00	1.14;	-9.54	-12.00	1.60;	-29.50	-4.00	-0.36;
-29.50	-12.00	-0.36;	-9.44	4.00	-2.90;	-26.43	4.00	-3.29;

Figure A-5. (Continued)

```
 -26.43   -4.00   -3.29;   -9.44   -4.00   -2.90;   -9.54    4.00    1.60;
 -29.54    4.00    1.14;  -29.54   -4.00    1.14;   -9.54   -4.00    1.60;
 -29.50    4.00   -0.36;  -29.50   -4.00   -0.36;   -9.44   12.00   -2.90;
 -26.43   12.00   -3.29;  -26.43    4.00   -3.29;   -9.44    4.00   -2.90;
  -9.54   12.00    1.60;  -29.54   12.00    1.14;  -29.54    4.00    1.14;
  -9.54    4.00    1.60;  -29.50   12.00   -0.36;  -29.50    4.00   -0.36;


LOAD: add  2 new loads in this load step.

Load #  11 (in fabricate coor.): 10000.0   30.0   24.0    4.5
Load #  12 (in fabricate coor.):-10000.0  -10.0    0.0    4.5

LOAD: Barge orientation before new loads      0.00    -1.31     0.00

 *** Current postions of the loads. ***

LOAD: (water coord.) #  1           20000.0       0.456     0.000     1.829
LOAD: (water coord.) #  2          -10000.0       0.456     0.000     1.829
LOAD: (water coord.) #  3            5000.0       0.456   -12.000     1.829
LOAD: (water coord.) #  4            5000.0       0.456    12.000     1.829
LOAD: (water coord.) #  5           10000.0     -29.537     0.000     1.141
LOAD: (water coord.) #  6           10000.0      30.448     0.000     2.517
LOAD: (water coord.) #  7           10000.0      10.453    -4.000     2.058
LOAD: (water coord.) #  8           10000.0      10.453     4.000     2.058
LOAD: (water coord.) #  9           10000.0      20.450     0.000     2.288
LOAD: (water coord.) # 10           50000.0     -19.539     0.000     1.371
LOAD: (water coord.) # 11           10000.0      20.450    12.000     2.288
LOAD: (water coord.) # 12          -10000.0     -19.539   -12.000     1.371

LOAD: Barge weight including loads    233060.    -0.378     1.030     0.752
      Unbalanced forces due to new loads:         0.  -240000.   399894.


 <<<<< LOAD STEP  8 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft  =      3.61 feet,
     heel angle (roll)     =    -3.53 degrees,
     trim angle (pitch)    =    -0.44 degrees.

  -9.82  -12.23   -2.01;   10.18  -12.21   -1.85;   10.18   -4.22   -2.35;
  -9.82   -4.25   -2.50;   -9.85  -11.96    2.48;   10.15  -11.93    2.64;
  10.15   -3.94    2.15;   -9.85   -3.97    1.99;   -9.82   -4.25   -2.50;
  10.18   -4.22   -2.35;   10.18    3.76   -2.84;   -9.82    3.74   -2.99;
  -9.85   -3.97    1.99;   10.15   -3.94    2.15;   10.15    4.04    1.65;
  -9.85    4.01    1.50;   -9.82    3.74   -2.99;   10.18    3.76   -2.84;
  10.18   11.75   -3.33;   -9.82   11.72   -3.48;   -9.85    4.01    1.50;
  10.15    4.04    1.65;   10.15   12.03    1.16;   -9.85   12.00    1.01;
  10.18  -12.21   -1.85;   27.18  -12.18   -1.72;   27.18   -4.20   -2.22;
  10.18   -4.22   -2.35;   10.15  -11.93    2.64;   30.15  -11.90    2.79;
  30.15   -3.92    2.30;   10.15   -3.94    2.15;   30.16  -12.00    1.29;
  30.16   -4.01    0.80;   10.18   -4.22   -2.35;   27.18   -4.20   -2.22;
  27.18    3.79   -2.71;   10.18    3.76   -2.84;   10.15   -3.94    2.15;
  30.15   -3.92    2.30;   30.15    4.07    1.81;   10.15    4.04    1.65;
  30.16   -4.01    0.80;   30.16    3.97    0.31;   10.18    3.76   -2.84;
  27.18    3.79   -2.71;   27.18   11.77   -3.20;   10.18   11.75   -3.33;
  10.15    4.04    1.65;   30.15    4.07    1.81;   30.15   12.05    1.31;
  10.15   12.03    1.16;   30.16    3.97    0.31;   30.16   11.96   -0.18;
```

Figure A-5 (Continued)

```
 -9.82   -4.25   -2.50;  -26.82   -4.27   -2.63;  -26.82  -12.25   -2.14;
 -9.82  -12.23   -2.01;   -9.85   -3.97    1.99;  -29.85   -4.00    1.84;
-29.85  -11.98    2.33;   -9.85  -11.96    2.48;  -29.84   -4.09    0.34;
-29.84  -12.07    0.83;   -9.82    3.74   -2.99;  -26.82    3.71   -3.12;
-26.82   -4.27   -2.63;   -9.82   -4.25   -2.50;   -9.85    4.01    1.50;
-29.85    3.99    1.35;  -29.85   -4.00    1.84;   -9.85   -3.97    1.99;
-29.84    3.90   -0.15;  -29.84   -4.09    0.34;   -9.82   11.72   -3.48;
-26.82   11.70   -3.61;  -26.82    3.71   -3.12;   -9.82    3.74   -2.99;
 -9.85   12.00    1.01;  -29.85   11.97    0.85;  -29.85    3.99    1.35;
 -9.85    4.01    1.50;  -29.84   11.88   -0.64;  -29.84    3.90   -0.15;


LOAD: add  1 new loads in this load step.

Load #  13 (in fabricate coor.): 10000.0    0.0    0.0    0.0

LOAD: Barge orientation before new loads    -3.53   -0.44    0.00

 *** Current postions of the loads. ***

LOAD: (water coord.) #  1          20000.0      0.148     0.035     1.823
LOAD: (water coord.) #  2         -10000.0      0.148     0.035     1.823
LOAD: (water coord.) #  3           5000.0      0.148   -11.942     2.561
LOAD: (water coord.) #  4           5000.0      0.148    12.012     1.084
LOAD: (water coord.) #  5          10000.0    -29.851    -0.005     1.593
LOAD: (water coord.) #  6          10000.0     30.147     0.074     2.052
LOAD: (water coord.) #  7          10000.0     10.147    -3.945     2.145
LOAD: (water coord.) #  8          10000.0     10.147     4.040     1.653
LOAD: (water coord.) #  9          10000.0     20.147     0.061     1.976
LOAD: (water coord.) # 10          50000.0    -19.852     0.009     1.670
LOAD: (water coord.) # 11          10000.0     20.147    12.038     1.237
LOAD: (water coord.) # 12         -10000.0    -19.852   -11.969     2.408
LOAD: (water coord.) # 13          10000.0     -9.827   -12.241    -2.006

LOAD: Barge weight including loads    243060.    -1.078     0.452     0.586
      Unbalanced forces due to new loads:    10000.   122407.   -98274.


 <<<<< LOAD STEP  9 >>>>>


     WETCAN: Equilibrium shape of the barge.
     Approximate draft  =     3.45 feet,
     heel angle (roll)    =    -1.75 degrees,
     trim angle (pitch)   =    -0.65 degrees.

 -9.72  -12.12   -2.53;   10.28  -12.10   -2.30;   10.28   -4.10   -2.55;
 -9.71   -4.12   -2.77;   -9.77  -11.98    1.97;   10.23  -11.96    2.19;
 10.23   -3.97    1.95;   -9.77   -3.99    1.72;   -9.71   -4.12   -2.77;
 10.28   -4.10   -2.55;   10.29    3.89   -2.79;   -9.71    3.87   -3.02;
 -9.77   -3.99    1.72;   10.23   -3.97    1.95;   10.23    4.03    1.71;
 -9.76    4.01    1.48;   -9.71    3.87   -3.02;   10.29    3.89   -2.79;
 10.29   11.89   -3.04;   -9.71   11.87   -3.26;   -9.76    4.01    1.48;
 10.23    4.03    1.71;   10.24   12.03    1.46;   -9.76   12.01    1.24;
 10.28  -12.10   -2.30;   27.28  -12.08   -2.11;   27.28   -4.08   -2.36;
 10.28   -4.10   -2.55;   10.23  -11.96    2.19;   30.23  -11.94    2.42;
 30.23   -3.94    2.18;   10.23   -3.97    1.95;   30.25  -11.99    0.92;
 30.25   -3.99    0.68;   10.28   -4.10   -2.55;   27.28   -4.08   -2.36;
 27.28    3.91   -2.60;   10.29    3.89   -2.79;   10.23   -3.97    1.95;
 30.23   -3.94    2.18;   30.23    4.05    1.93;   10.23    4.03    1.71;
```

Figure A-5. (Continued)

```
|........1.........2      Descriptions.

2 ...................... Number of unique cans.
OLD .................... Pick existing can from CANSHELF.
ISO 20 ................. Name of the can selected.
NEW  ................... Construct a new can.
RAKE END 20  .......... Name of the can to be constructed.
16  .................... Number of nodes in the unique can.
0. 0. 0.  .............     -------------------------
17. 0. 0.  ............              /|\
17. 8. 0.  ............               |
0. 8. 0.   ............ Position coordinates of node points in
0. 0. 4.5  ............ local coordinate system (See figure    ).
20. 0. 4.5 ............               |
20. 8. 4.5 ............               |
0. 8. 4.5  ............               |
20. 0. 3.  ............              \|/
20. 8. 3.  ............      --------------------------
1          ............ Number of material types used in the can.
22.5  ................. Density of material type 1.
7     ................. Number of plates of the can.
1 4 4 3 2 1  ..........      ---------------------------
1 4 5 6 7 8  ..........              /|\
1 4 1 5 8 4  ..........               |
1 4 2 3 10 9  ......... Material type, number of vertices, and
1 4 9 10 7 6  ......... Node number of each vertices of the plates.
1 5 1 2 9 6 5 ........               \|/
1 5 3 4 8 7 10 .......       ----------------------------
15    ................. Number of edges of the can.
1 2   .................      ----------------------------
2 3   .................              /|\
3 4   .................               |
4 1   .................               |
5 6   .................               |
6 7   .................               |
7 8   .................               |
8 5   ................. Node numbers of the ends of each edge.
1 5   .................               |
4 8   .................               |
2 9   .................               |
9 6   .................               |
3 10 ..................               |
10 7 ..................              \|/
9 10 ..................      ----------------------------
146   ................. Nominal deck area of the can.
N    .................. Do not store this new can in the CANSHELF.
0    .................. Select default reference frame for barge fabrication.

|........1.........2
```

Figure A-6.
Sample input file for ISAP Version 1.1 for a 3 by 3 ISO pontoon barge analysis.

```
|........1.........2        Descriptions.

9 .........................  number of cans of the barge.
1 0. 0. 0. 1 2 1 3 .......       ---------------------
1 0. 8. 0. 1 2 1 3 .......                /|\
1 0. 16. 0. 1 2 1 3 .......                |
2 20 0. 0. 1 2 1 3 .......   unique can type, location of can origin,
2 20. 8. 0. 1 2 1 3 ......   and the directions of the x- and y- axis
2 20. 16. 0. 1 2 1 3 .....   of the can. (See figure    ).
2 0. 8. 0. 2 1 3 1 .......                 |
2 0. 16. 0. 2 1 3 1 ......                \|/
2 0. 24. 0. 2 1 3 1 ......         ----------------------
1 ........................   Number of loads in this load step.
20000. 10. 12. 4.5 .......   Weight, and its position coordinates.
1 ........................   Select 'add loads' option, (See, page    ).
1 ........................   Number of loads in this load step.
-10000.  10. 12. 4.5 .....   Weight, and its position coordinates.
1 ........................   Select 'add loads' option, (See, page    ).
2 ........................   Number of loads in this load step.
5000.  10. 0. 4.5     .....  Weight, and its position coordinates.
5000.  10. 24. 4.5    .....  Weight, and its position coordinates.
1 ........................   Select 'add loads' option, (See, page    ).
1 ........................   Number of loads in this load step.
10000. -20. 12. 4.5   .....  Weight, and its position coordinates.
1 ........................   Select 'add loads' option, (See, page    ).
1 ........................   Number of loads in this load step.
10000. 40. 12. 4.5    .....  Weight, and its position coordinates.
1 ........................   Select 'add loads' option, (See, page    ).
3 ........................   Number of loads in this load step.
10000. 20.  8. 4.5    .....  Weight, and its position coordinates.
10000. 20. 16. 4.5    .....  Weight, and its position coordinates.
10000. 30. 12. 4.5    .....  Weight, and its position coordinates.
1 ........................   Select 'add loads' option, (See, page    ).
1 ........................   Number of loads in this load step.
50000.  -10. 12. 4.5 .....   Weight, and its position coordinates.
1 ........................   Select 'add loads' option, (See, page    ).
2 ........................   Number of loads in this load step.
10000. 30. 24. 4.5    .....  Weight, and its position coordinates.
-10000. -10. 0. 4.5   .....  Weight, and its position coordinates.
4 ........................   Select 'exit' to terminate execution. (See, page    ).

|........1.........2
```

Figure A-6. (Continued)

30.25	-3.99	0.68;	30.25	4.01	0.43;	10.29	3.89	-2.79;
27.28	3.91	-2.60;	27.29	11.91	-2.84;	10.29	11.89	-3.04;
10.23	4.03	1.71;	30.23	4.05	1.93;	30.24	12.05	1.69;
10.24	12.03	1.46;	30.25	4.01	0.43;	30.25	12.00	0.19;
-9.71	-4.12	-2.77;	-26.71	-4.14	-2.97;	-26.72	-12.14	-2.72;
-9.72	-12.12	-2.53;	-9.77	-3.99	1.72;	-29.76	-4.01	1.50;
-29.77	-12.00	1.74;	-9.77	-11.98	1.97;	-29.75	-4.05	0.00;
-29.75	-12.05	0.24;	-9.71	3.87	-3.02;	-26.71	3.85	-3.21;
-26.71	-4.14	-2.97;	-9.71	-4.12	-2.77;	-9.76	4.01	1.48;
-29.76	3.99	1.25;	-29.76	-4.01	1.50;	-9.77	-3.99	1.72;
-29.75	3.94	-0.25;	-29.75	-4.05	0.00;	-9.71	11.87	-3.26;
-26.71	11.85	-3.45;	-26.71	3.85	-3.21;	-9.71	3.87	-3.02;
-9.76	12.01	1.24;	-29.76	11.98	1.01;	-29.76	3.99	1.25;
-9.76	4.01	1.48;	-29.74	11.94	-0.49;	-29.75	3.94	-0.25;

Figure A-6.(Continued)

```
001:  ISO 20
002:  8
003:  0. 0. 0.
004:  20. 0. 0.
005:  20. 8. 0.
006:  0. 8. 0.
007:  0. 0. 4.5
008:  20. 0. 4.5
009:  20. 8. 4.5
010:  0. 8. 4.5
011:  1
012:  22.7
013:  6
014:  1 4 4 3 2 1
015:  1 4 5 6 7 8
016:  1 4 1 5 8 4
017:  1 4 2 3 7 6
018:  1 4 1 2 6 5
019:  1 4 3 4 8 7
020:  12
021:  1 2
022:  2 3
023:  3 4
024:  4 1
025:  5 6
026:  6 7
027:  7 8
028:  8 5
029:  1 5
030:  4 8
031:  2 6
032:  3 7
033:  160.
034:  ISO 40
035:  8
036:  0. 0. 0.
037:  40. 0. 0.
038:  40. 8. 0.
039:  0. 8. 0.
040:  0. 0. 4.5
041:  40. 0. 4.5
042:  40. 8. 4.5
043:  0. 8. 4.5
044:  1
045:  45.
046:  6
047:  1 4 4 3 2 1
048:  1 4 5 6 7 8
049:  1 4 1 5 8 4
050:  1 4 2 3 7 6
051:  1 4 1 2 6 5
052:  1 4 3 4 8 7
053:  12
054:  1 2
055:  2 3
056:  3 4
057:  4 1
058:  5 6
059:  6 7
060:  7 8
061:  8 5
062:  1 5
063:  4 8
064:  2 6
065:  3 7
066:  320.
067:  RAKE END 20
068:  10
069:  0. 0. 0.
070:  17. 0. 0.
071:  17. 8. 0.
072:  0. 8. 0.
073:  0. 0. 4.5
074:  20. 0. 4.5
075:  20. 8. 4.5
076:  0. 8. 4.5
077:  20. 0. 3.
078:  20. 8. 3.
079:  1
080:  22.5
081:  7
082:  1 4 4 3 2 1
083:  1 4 5 6 7 8
084:  1 4 1 5 8 4
085:  1 4 2 3 10 9
086:  1 4 9 10 7 6
087:  1 5 1 2 9 6 5
088:  1 5 3 4 8 7 10
089:  15
090:  1 2
091:  2 3
092:  3 4
093:  4 1
094:  5 6
095:  6 7
096:  7 8
097:  8 5
098:  1 5
099:  4 8
100:  2 9
101:  9 6
102:  3 10
103:  10 7
104:  9 10
105:  146
```

Figure A-7.
Sample file for "CANSHELF."

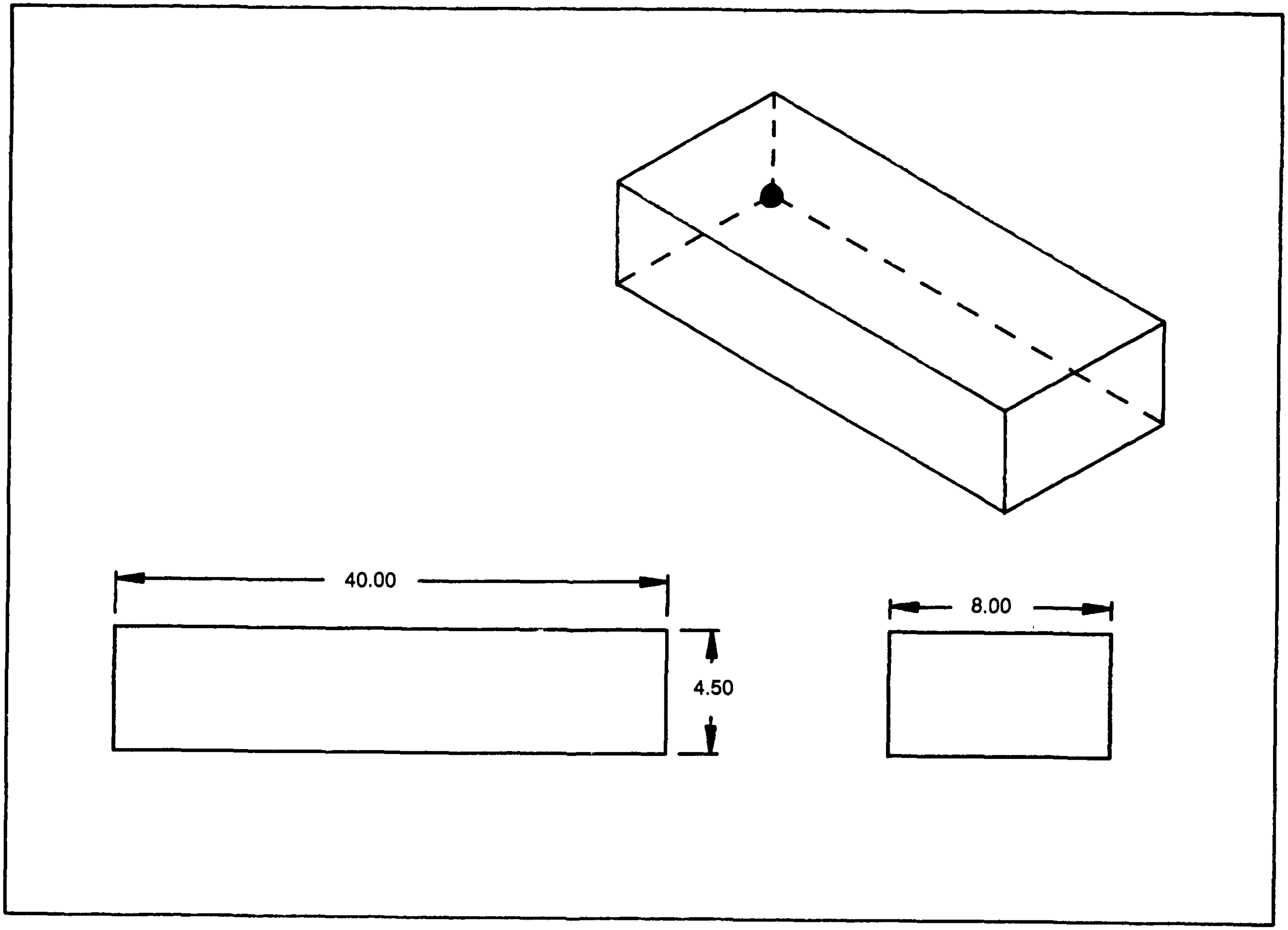


Figure A-8.
Sketch of ISO-40 pontoon.

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